metal finishing Journal

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THIS JOURNAL IS DEVOTED TO THE SCIENCE AND TECHNOLOGY OF PAINT APPLICATION, ELECTRODEPOSITION, VITREOUS ENAMELLING, GALVANIZING, ANODIZING, METAL SPRAYING & ALL METAL FINISHING PROCESSES. THE EDITOR IS PREPARED TO CONSIDER FOR PUBLICATION ANY ARTICLE COMING WITHIN THE PURVIEW OF "METAL FINISHING JOURNAL" AND ALL SUCH ARTICLES ACCEPTED WILL BE PAID FOR AT THE USUAL RATES.

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PIGMENTS

18A

BEAUTY IS NOT ENOUGH

AS a result of the considerable influence that an attractive and colourful finish can have upon sales, there is a tendency among metal finishers to place undue emphasis upon this aspect of their industry and to under-rate the necessity for adequate life and performance in service. A brightly coloured or highly polished surface can undoubtedly promote sales, but if the finish fails to give a good account of itself, subsequently it can bring both the finish and the article to which it is applied into disrepute.

Blistered chromium plate, flaking paint coatings, chipped enamel, have all been the subject of consumer criticism in recent years to such an extent that in some cases the impression has been given that manufacturers are only concerned with getting the goods out of their works and are completely indifferent to their subsequent behaviour. If such an impression were permitted to go uncorrected and to gain wider credence it could do untold harm to any sales effort, and it is therefore important that its fallacy should be revealed.

Its fallaciousness is in fact clearly pinpointed by even the most superficial study of metal finishing literature. A very substantial proportion of the writing on metal finishing subjects is directed towards improving the performance of various types of finish, and the accent of all editorial exhortations is very heavily in favour of manufacturers adopting every means in their power to ensure that the finish they apply is not only superficially attractive but also intrinsically sound.

In the present issue of this Journal, for example, two contributions are devoted to the subject of performance testing of widely differing finishes, and the discussion which followed the presentation of one such paper at the recent Conference of the Institute of Vitreous Enamellers, revealed that not only the suppliers of enamels but the enamellers themselves and the distributors of finished goods are all keenly aware of the need for improving in every way possible the performance of the finish.

The finishes which are available to industry today are in themselves capable of putting up a very effective performance and sufficient is now known about the techniques of applying them for it to be possible to ensure that each finish shall operate at its maximum efficiency. When finishing defects do appear in service it is very nearly always due to some inadequacy in its application technique, usually stemming from economic motives.

For example, the provision of a sound, clean, uniform surface on the metal prior to the application of a finish is absolutely fundamental, and its omission, or only partial commission is almost invariably inconsistent with obtaining a satisfactory finish. The provision of a clean surface on a fabricated component not infrequently presents some difficulty arising from the shape of the component or the nature of the contaminant. Therefore the provision of a metal sheet which has been scrupulously cleaned in sheet form and then given a protective coating prior to fabrication should prove of considerable benefit from the point of view of its subsequent finishing. Such material has been available on a limited scale in this country for some years, and with increasing production capacity, particularly for electrolytically zinc-coated sheets, the supply will undoubtedly increase. The assumption by the steel sheet manufacturer of some of the onus of responsibility for providing a chemically-clean surface should go far towards dispelling any inadequacies of the finish arising from ineffective pre-treatment.

Talking Points

by "PLATELAYER"

TOPICAL COMMENT FROM THE MAIN LINES AND SIDE LINES OF METAL FINISHING

GIPSY BOFFINS

THE emergence of the caravan trailer from a holiday home to a useful industrial adjunct began years ago, but it is likely that its versatility and usefulness in this direction will expand much more rapidly in the near future with the growing dispersal of industry. Mobile banks, shops, libraries and exhibitions are already commonplace, but the mobile laboratory is still in its infancy. Recently the Ministry of Supply equipped the Outdoor Exposure Station in Wales with a trailer laboratory on the site for the inspection of test panels, which number about 3,000. This, however, is not a truly mobile laboratory, as it remains in one location most of the time.

We may yet see firms in the metal treatment and electroplating supply business sending their service chemists out with fully equipped trailer laboratories to their customers both to analyse solutions and investigate production problems on the spot. This will eliminate the need for sending samples of solutions etc., for examination with all the trouble and delay that this involves. In fact it might well be that the smaller firms running their own laboratories would dispense with them if they could be assured of the regular service of a travelling laboratory parked at their own back door. Large firms, with a number of factories, might likewise decide to replace small inefficient branch laboratories at outlying works by trailers to provide a service from a central laboratory as required.

Perhaps one of the laboratory supply firms could start a move in this direction by offering a standard trailer laboratory ex stock.

STYGIAN GLOOM WITHIN

WE see that an American company is now marketing plating barrels lined with white polyvinyl chloride. The advantages of a white or light-coloured lining for plating plant and tanks are tremendous, as anyone who has used a white-lined nickel plating vat, or one made of resin-glass, for instance, will appreciate. Positions of articles on racks, work on the tank floor, anode locations and so on can easily be seen, which helps a great deal in maintaining efficient working of the installation.

It is of course, understandable that there are difficulties in the way of producing white rubber linings of adequate chemical resistance at a reasonable cost, so that we have perforce had to put up with the prevailing poor visibility of tank interiors. What is less understandable is that plastic lined tanks, which are becoming increasingly-popular, are still being produced in black or very dark colours.

There is no reason for this, since light-coloured plastic lining materials are just as easy to manufacture and cost no more. Now that we have the materials to do it with, why not shed some light on the proceedings ?

CLEANING THE SILVER

SOME recent correspondence in "The Times" on the subject of black stains on silver-plate which defy removal, has caused consternation in silverware circles. The Master Silversmiths Association has received many complaints often reflecting on the quality of present day electroplating.

Investigations by the Sheffield Smelting Company and others indicate that the stains can be produced by solid salt or detergent particles falling on the silver during washing, particularly in detergent solutions. These solutions clean the metal so thoroughly that table salt particles will attack the silver to an extent which does not occur when soap or non-detergent cleaning methods are used. The answer is not to wash silver in detergents, if possible. Alternatively, a liquid detergent should be used, but if this is impracticable to make sure the powder is thoroughly dissolved. Salt particles should be prevented from falling onto the silver from dinner plates by washing the former first.

Curiously enough the stains can best be removed by putting the silver in a hot strong solution of common salt, followed by polishing !

BLACK AND WHITE

THE Chrysler Corporation reports that this year the most popular colour for its cars was white, either in single tones or in combination use. The number two position was occupied by black. Curiously enough, white cars are still rather few and far between on this side of the Atlantic, although black is still highly popular.

As it was quite a long time before colourful cars become common in Britain, presumably it will be a few years before we see many white cars here. White cars have the advantage of being cooler in hot weather, and more easily visible in the dark, which makes for safety. But they do take a lot of cleaning !

Methods used in the performance TESTING OF PAINT

4. GLOSS, HIDING POWER, REFLECTANCE

by W. V. MOORE, B.A.

(*Continued from page* 288, *July*, 1957)

Gloss

WHEN light falls upon an object some is immediately reflected regularly from the surface while the remainder passes through the surface and enters the object. The amount reflected depends upon the difference in the refractive indices of the medium through which the light is travelling and the object from which it is reflected, and also upon the angle of incidence. Gloss is a measurement of the proportion of reflected light.

An instrument which measures the proportion of incident light specularly reflected from a surface will therefore give a fair measurement of the gloss of that surface. Also if the measurement is always made at the same angle of incidence, then results will be comparable. However, results obtained in this fashion are not always acceptable visually because the observer is affected by phenomena not directly connected with the gloss. Thus if a black and a white surface, both of which reflect the same proportion of incident light, are compared visually, the black surface will appear glossier than the white. This is due to the behaviour of that portion of the light which is not reflected by the surface ; after passing through the surface of a paint film the light comes into contact with the pigment particles dispersed in it. Here it can once more be either reflected or absorbed according to the nature of the pigment. Black will absorb nearly all the light, white will reflect a large proportion, green will reflect the light in the green part of the spectrum and absorb the remainder, etc. This reflected light will then pass back through the paint-air interface to be seen by the observer. Since, however, the pigment particles are normally under random orientation in a paint film, the light will also be randomly reflected and leave the paint film having an equal intensity at all angles. It is a diffuse reflection as opposed to the specular reflection from the surface. Now the human eye, in estimating gloss, automatically compares the light reflected from the surface with the total light reflected, and thus the black surface having a lower diffuse reflection, appears glossier than the white.

This differentiation by the eye can be of great importance when comparing the gloss of clear satin lacquers. Two lacquers giving the same reading on a glossmeter may in fact appear completely different ; one having a " dead " look while the other retains a good " depth of finish ". The difference is due to the variation in the amount of diffuse reflection from the matting agents incorporated in the two lacquers. The one which has the higher diffuse reflection resulting in a lower reflection from the substrate is the one which has the " dead " look.

Surface imperfections in the film can also give trouble in making visual estimations of gloss. Brush marks, or pieces of dust embedded in the surface make it much easier for the eye to fix its position and since part of the subjective sensation of gloss lies in failure to determine the position of the surface, this reduces the apparent gloss. This also applies if the surface imperfections are not widespread. If the surface is covered with dust then obviously a great deal of light will be absorbed by it and the surface will actually be less glossy. But if the bits are few then a glossmeter will give a truer reading since it needs a smaller surface to work on than the eye and is less distracted by small blemishes.

The effect of the angle of incidence upon the gloss must also be considered. A quick method of comparing the gloss of two paints is to hold them up towards the light from a window and compare the sharpness of the image of the window-frame in each surface. This is a very convenient method, but it must always be remembered that a variation in the angle of incidence will also vary the gloss so that if several paints are to be compared they should all be presented for comparison at the same time to eliminate the variation. It is also as well to have a standard ready for comparison as it is only too easy to overestimate the gloss of a paint simply by increasing the angle of incidence to give increased reflection.

The principle of estimating gloss by comparison of the sharpness of reflected images has been used in several instruments although it should be noted that comparison of results is not possible because of the varying angles of incidence. The method is only suitable for high angles of incidence and

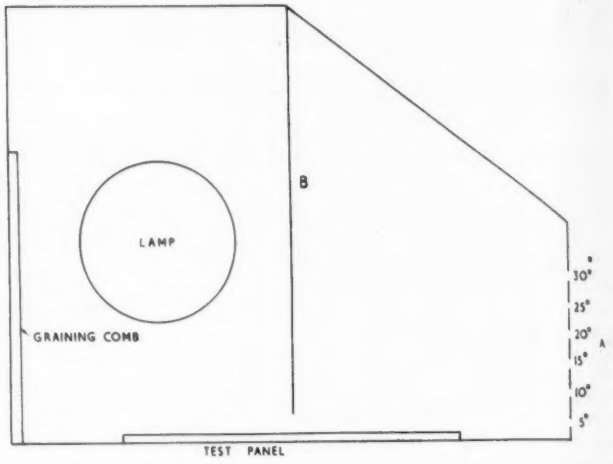


Fig. 10—Diagram of apparatus for estimating gloss according to Defence Specification 1053.

the measurement is then said to be one of sheen rather than gloss which is generally measured at fairly low angles of incidence (45 deg. or 60 deg.). Such an instrument is given in Defence Specification 1053. In this case the image is provided by a graining comb. This is fitted to the rear surface of a small box as shown in Fig. 10. The bottom of the box is open so that it can be fitted over the surface to be tested while illumination is provided by a 60-watt lamp placed inside the box. The reflected image of the graining comb is viewed through the slots " A " cut in the front face of the box. These are so arranged that observations are made at angles of 5, 10, 15, 20 and 30 deg. The gloss is quoted as the greatest angle at which the image of the graining comb is seen to be sharply defined.

In order to prevent the observer being dazzled by light shining directly into his eyes, a partition " B " is placed across the centre of the box between the lamp and the slots. This does not quite reach the bottom of the box so that the image of the graining comb is not obscured. The whole of the interior of the box is painted a matt black to eliminate stray reflections while the graining comb is mounted upon a white card for ease of observation.

This instrument will give consistent results provided the surfaces to be measured are carefully prepared and free from brush-marks or other surface defects, but its powers of discrimination are not very high since there are only seven possible points on the scale. It is not suitable for use on high-gloss surfaces as these lie well beyond the upper limit of the instrument.

The limitations upon the sensitivity of gloss measurement, which occur with visual estimation because of the lack of sensitivity of the eye and its lack of objectivity, can be overcome by using a photoelectric gloss-meter. In this type of instrument a photoelectric cell is used to measure the intensity of the reflected light ; comparison being made with the intensity from a standard surface. A diagram of the measuring head of

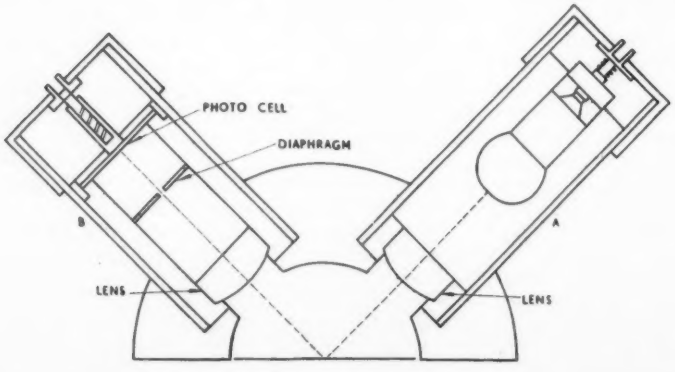


Fig. 11—Diagram of measuring head of photoelectric gloss measuring equipment (the EEL instrument)

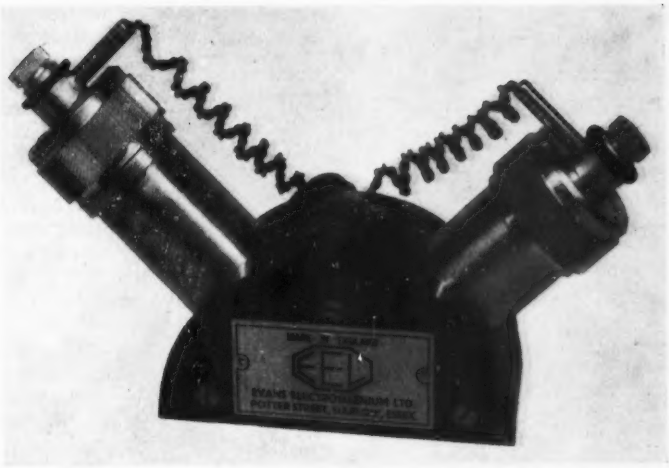


Fig. 12—Photograph of apparatus shown diagrammatically in Fig. 11 (Courtesy of Evans Electroselenium Ltd.)

such an instrument is shown in Fig. 11 and a photograph of the complete instrument in Fig. 12.

In the diagram, " A " is a lamp-house containing a car head-lamp bulb as the source of reflected light. The light from the bulb is made parallel by a lens system and then directed upon the surface to be tested at an angle of 45 deg. Light reflected from the surface is collected by a second lens, situated in the photo-cell housing " B ", and forms an image of the bulb filament in its focal plane. At this point there is a diaphragm, whose aperture is only slightly larger than that of the filament of the bulb, so that the angular spread of light is restricted and only light specularly reflected from the surface is allowed to pass. Behind the diaphragm is the photo-cell which receives the reflected light and converts it into an electric current. The current so produced is measured on a separate spot-type galvanometer with a scale of 100 divisions. Photo-cell output and galvanometer sensitivity can be matched by means of a variable resistance on the galvanometer.

The standard of gloss against which the instrument is calibrated consists of a piece of optically flat, black plate glass with a refractive index of 1.520. Alternatively, a piece of clear glass with the same refractive index, may be used, if the under surface is first coated with a matt black paint. The gloss of this standard surface is taken to be 100.

To operate the instrument the glossmeter head is placed upon the standard black surface with the light switched off and the galvanometer adjusted to read zero on the scale. Then the light is switched on and the potentiometer adjusted until a reading of 100 is obtained on the scale. This fixes the gloss scale. Finally the head is transferred to the test surface and the reading of the galvanometer noted at several positions on the surface. The gloss is then given by the mean of the readings obtained.

When making measurements frequent checks should be made against the gloss standard since the output of the photoelectric cell is inclined to drift.

This glossmeter gives reliable and reproducible results but cannot be used for surfaces with low gloss. This is because, although the instrument is designed to collect light with only a small angular spread to reduce the acceptance of diffusely reflected light, it does collect light which is diffusely reflected at 45 deg. The error involved is very small for surfaces of high gloss but is not negligible for light coloured surfaces of low gloss in which the specular reflection is low and the diffuse reflection comparatively high.

Here then is a type of instrument which gives an objective value for the gloss of a surface and one which is of great value in development work where a large number of surfaces may have to be compared over an interval of time. Unfortunately the final arbiter, the paint user, is not at all concerned with an objective value but simply with what his product looks like. He is not concerned that two surfaces appear to have a different gloss because they are of different colours. His only concern is that they shall look alike. A further complication is that the gloss of a paint film is not a static value but varies considerably especially during the early life of the film before it is properly cured. Some compromise must therefore be reached between those methods which are subject to so many outside influences that their reproducibility is affected and those which are objective in themselves but thereby lose some of their direct usefulness to the consumer.

Hiding Power

The hiding power of a paint is a measure of its ability to obliterate the colour of the substrate. This does not include the ability to cover changes

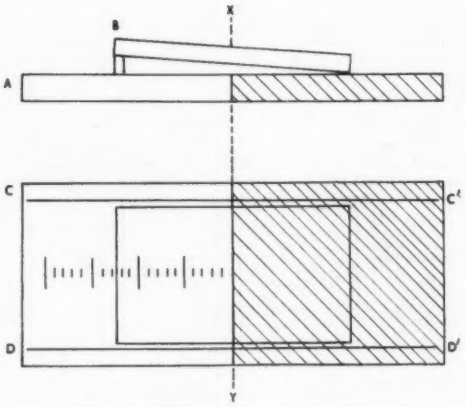


Fig. 13—*Diagram of the Cryptometer*

in texture of the surface, a factor which should always be borne in mind since the two effects are sometimes difficult to differentiate. For example, when a partly painted wall is completely repainted with a paint of a different colour it is often possible to see the edge of the original paint as a dark shadow running along the wall. This is probably due, not to poor hiding power, but to the differences in absorptive properties between the painted and unpainted sections. This is an extreme case, but it is always as well to check that apparent poor hiding power is not in fact due to variations in the surface.

Total obliteration of the substrate will occur when all the light which passes into the paint film is either reflected or absorbed by the film and the particles dispersed in it. As a general rule, both the paint medium and the pigment particles are either transparent or translucent when viewed in bulk and the ability to reflect light is due to the large number of interfaces which the light encounters as it passes through the film. Good dispersion of the pigment with the consequent formation of a large number of surfaces is therefore a necessary condition for good hiding power. This is illustrated by the very marked reduction in hiding power which occurs when the pigment in a paint becomes flocculated.

The refractive indices of the medium and the pigments also plays a large part in determining hiding power. The amount of light reflected at an interface depends on the difference between the refractive indices of the two media forming the interface ; the larger the difference the greater is the amount of light reflected. Hence titanium dioxide which has a refractive index of 2.70 gives much better hiding than blanc fixe with a refractive index of 1.64. In this respect small air bubbles with their low refractive index would also give good hiding power if they could be kept suspended in the film.

The exact reverse of good hiding power is required when an extender is used to make a full-gloss lacquer into a satin. Here we want a substance which will reduce the gloss without making the film opaque so that an extender whose refractive index is as nearly as possible the same as that of the dry medium is required.

Perhaps the simplest way to measure hiding power is to find out what thickness of paint or what weight per unit area is required completely to cover a dark background. This is the method used by the cryptometer :—

The Cryptometer

A diagram of this instrument is shown in Fig. 13. It consists of a base A comprising two sheets of plate glass, one white and one black, ground optically flat and fused together along the line XY. Both sheets of glass have a scale etched into the surfaces showing distances from the line XY. The reflectances of the white and black halves are 80.5 per cent. and 5 per cent. respectively. A piece of clear glass B, also optically flat rests upon A with one end raised by a strip of metal 0.45 mm. thick so that a wedge-shaped gap is formed between the two.

To operate the instrument a few drops of paint are placed on A and the sheet B laid on top, care being taken to see that no air bubbles are trapped underneath. Excess paint squeezed out from between the plates is contained by two small grooves cut longitudinally in A. (C.C^1 and D.D^1 in the diagram). B is now moved slowly across A until the line between the black and white halves of the plate is no longer visible through the paint film. The distance of the point of the wedge from the centre-line is now read off on the scale and the process repeated, this time for the reappearance of the line. The thickness of paint above the centre-line can then be obtained from the angle of the wedge and the distance from the centre.

Readings for appearance and disappearance of the line are necessary because the fading out is gradual as the eye can only detect increments of intensity of about 2 per cent. It is also a greater aid to accuracy if the upper plate is reversed, so that the positions of the black and white portions are transposed, and the readings repeated. An average of the series will then give a value having a fair degree of reproducibility.

The value obtained is the wet film thickness of paint required completely to hide a black and white surface having a difference in reflectance of 75.5 per cent. The value really required is the dry film thickness required to give complete hiding but it is claimed that these values are very nearly equal and lie within the limits of accuracy of the method. This is probably true in a great number

of cases but there are times when there is a large difference between the hiding of the wet and dry films which can be due to the following reasons :— (1) The presence of solvents of low refractive index in the medium increases the difference between the refractive index of the medium and the refractive index of the pigments. Hence the hiding power of the wet film is greater than that of the dry film. This effect always occurs and is not usually very large. (2) The pigment in the medium may tend to flocculate as the film dries resulting in a reduction in the number of reflecting surfaces, and a decrease in hiding power. The extent of flocculation may vary enormously and give rise to anomalous results. (3) If the critical pigment volume has been exceeded in the paint then a number of pigment/air interfaces will be formed as the film dries. Since the difference in the refractive indices of air and pigment is much greater than that between medium and pigment the total effect is markedly to increase the hiding power in the dry film.

Hiding Power Charts

In this method the paint is applied over a large surface which is divided into black and white portions. This may take the form of a chequer board or of black and white diamonds as in the Morest chart shown in Fig. 14. By weighing the chart before and after application the weight of paint needed to give complete covering can be obtained while a little further calculation enables the results to be expressed as square feet covered per gallon.

If it is found difficult to obtain complete hiding with one coat then two or more coats may be applied. But great care must always be taken to ensure that the paint is spread evenly over the surface. The method may also be used for comparison purposes at incomplete hiding by always brushing the same weight of paint onto the surface, and also for comparing the hiding power of different batches of the same paint. More reliable results are, in fact, obtained by using the charts at incomplete hiding and comparing the results with fixed standards because of the difficulty in assessing the point at which complete hiding is achieved.

Films painted onto different types of chart should not be compared because, first, the difference between the reflectances of the black and white portions must be kept constant (obviously it is easier to hide a panel in two shades of grey than in black and white) and, second, the shape of the pattern also partly decides the ease with which it can be covered.

The accuracy of this method is not very great since the final assessment depends upon the eye of the observer and the care with which the paint has been applied, but it does have the advantage of giving an easily understandable and permanent record.

Fig. 14—*The Morest hiding-power chart*

Contrast Ratio Test

Both the above methods depend upon visual estimation for their results and are therefore limited by the inability of the eye to distinguish small differences in light intensity. In the contrast ratio test the eye is replaced by a photoelectric cell which is used to measure the light intensity. Complete hiding is not measured but only the hiding at a given film thickness.

The principle of the method is as follows :— Consider first a film of paint applied to a substrate which will absorb all light falling upon it, and the effect of shining a beam of light, of intensity A, normally upon the surface. The light will be split into a fraction x which is absorbed by the paint film, a fraction y which is reflected by the pigment particles and a fraction z which is absorbed by the substrate so that

$$A = xA + yA + zA$$

or $$yA = A - xA - zA \quad . \quad . \quad . \quad . \quad (1)$$

Second, consider a film of paint of the same thickness applied to a substrate which reflects all light falling on it, and the effect of shining a beam of light of the same intensity upon it. The same fraction, x, as before will be absorbed but now the remainder will all be reflected. Let this remaining fraction be y_1,

Then $A = xA + y_1A$

or $y_1A = A - xA$ . . . . . (2)

Combining (1) and (2)

$$\frac{yA}{y_1A} = \frac{(A - xA) - zA}{(A - xA)}$$

$$\frac{y}{y_1} = \frac{(1 - x) - z}{(1 - x)}$$

Now it can readily be seen that the ratio $\frac{y}{y_1}$ is in fact a measure of the hiding power of the film since the fraction z is just that fraction which, when reflected by the substrate, renders it visible to the observer and declares the film lacking in hiding power. Perfect hiding power is shown by a contrast ratio of 1 which occurs when $z = 0$ and no light passes through the film into the substrate.

As in previous methods the reflectances of the black and white substrates are of great importance and the standards used in this test are surfaces of 5 per cent. and 85 per cent. reflectance compared with pure magnesium carbonate.

The surfaces used as a background when measuring y and y_1, are two black and white tiles about 3 in. square and these are periodically checked against a standard magnesium-carbonate block to ensure that their reflectances remain constant. In order that they may suffer no damage in use, the paint film is not applied directly to them but is cast upon transparent cellulose sheet at a wet film thickness of 0.002 in. When the paint has dried a small portion of this film is cut out and placed over the tiles. Good optical contact is ensured by first wetting the tiles with a few drops of white spirit and then carefully squeezing out all air bubbles from between the surfaces. This method of applying the film is also an advantage because the operator can choose his portion of film so that no dust particles, pin-holes, or other defects are included.

The instrument used for measuring the intensity

(*Continued in page* 395)

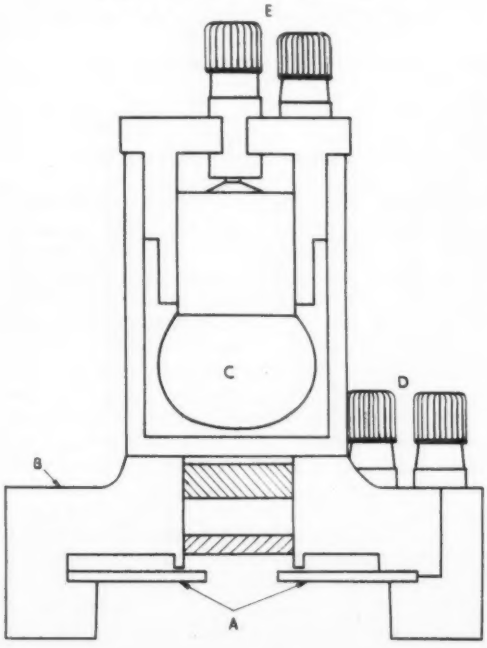


Fig. 15—*Diagram of reflectometer*

Fig. 16—*Photograph of reflectometer* (*Courtesy of Evans Electroselenium Ltd.*)

Performance Testing of Paint

(*Continued from page* 394)

of reflected light is shown diagrammatically in Fig. 15. It consists of a selenium barrier-layer photoelectric cell, A, which has a hole in the centre so that light from the source C can pass through it. C is an ordinary 6-volt electric-light bulb. B is the casing for the cell which is constructed so that, when the instrument is placed on a smooth surface, the cell lies parallel to and $\frac{1}{4}$ in. above it. Before passing through the cell the light is first passed through a heat filter and an opal glass screen. D and E are the connecting terminals for the photo-electric cell and the lamp respectively. The output from the cell is measured on a spot-type galvanometer with a scale of 100 divisions and a variable resistance to alter the sensitivity.

The mode of operation is as follows :—A portion about 2 in. square is cut from the paint film which has been cast into cellulose sheet. This is placed on the white tile and the detector placed on top of it. The galvanometer is now adjusted to read 100 on the scale (*i.e.* y_1 is made equal to 100). The same piece of film is then moved to the black tile when the galvanometer reading is the percentage contrast ratio (*i.e.* y is comparedwith y_1). Observations should be made over several different pieces of the film and the average value taken. A photograph of the complete instrument is shown in Fig. 16.

This method has the great advantage of being independent of the personal equation of the operator and of such errors in film thickness as may occur when a large area has to be covered. Film thickness errors are not, however, completely eliminated as it is found that film applicators deliver films of slightly different thickness according to the speed of application and the rheological properties of the paint. Some difficulty may also be encountered in preparing the paint film as the cellulose sheet tends to deteriorate on storage, giving wrinkled areas which cause thin spots in the film. Great care must be taken in preparing the film to be tested. If a film shows large numbers of irregularities, it is much better to throw it away and prepare a new one than to try and find the area with the fewest defects.

The results give an indication as to the hiding at constant film thickness. This is a disadvantage when the information required is the thickness of paint needed to hide a surface. But on the other hand, brushing or spraying paints with similar formulations generally results in films of approximately the same thickness, so that in this respect measurements made at equal thickness are an advantage.

A further point, which is perhaps worthy of mention, as it is well illustrated by the hiding power tests, is the impact of the results upon the observer. The contrast result is simply a number which does not have any immediate connection with the problem of covering a wall with paint, whereas the results obtained from a hiding power chart can be expressed in terms of square feet per gallon, a term of immediate significance. Also a visual comparison of two surfaces to determine differences in hiding power is more stimulating to the observer than the recording of two positions on a scale. This is not to suggest that pretty pictures are any substitute for accurate observation, but there can be no doubt that information attractively displayed for ready understanding and full appreciation is of far greater value than a mass of indigestible facts, however accurate.

(*To be continued*)

Vitreous Enamelling in Architecture — Discussion

(*Continued from page* 417)

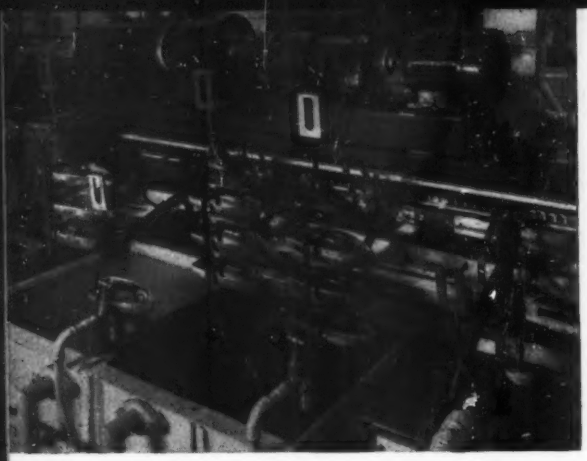
not use anything heavier than 20 gauge. There was no difficulty in flattening 16-gauge sheet. It was not possible to deal with localized or intermediate distortion, but the simple bulge could be straightened out. It was mainly a matter of the practice of the manufacturer.

He had been impressed by some of the things that he had seen done in cast iron, and he thought that excellent uses could be found for this material.

THE CHAIRMAN, replying to a comment by a member who said that he would like to see an 8-ft. x 4-ft. cast-iron sheet, remarked that he knew where some could be seen, and were even used as core benches, which had to be flat.

To the question of whether there were any blow-holes in them there was no reply.

MR. MCARTHUR, on the question of where the enameller's responsibility ended, said that ethically it never ended, because he was putting an element into a building which would be expected to have the life of the other elements which went into that building. Some American companies now gave a ten-year guarantee of the weathering properties, or in other words the durability, of the enamel finish. He thought that any enameller would be prepared to do that. The proved durability of enamelled steel was a good selling point. The Chairman suggested that the enameller's responsibility ended when he received his cheque, but if there was a problem such as delayed fishscale, which did not appear for six months, in Mr. McArthur's view the enameller should remove and replace the affected panels.



The NEW SEMI-AUTOMATIC PLATING SHOP *at* HOOVERS

High Wycombe Works

Fig. 1. Close-up view of the mechanism of the "Little Steve" automatic plating line.

Shop Details

THE new semi-automatic plating shop at the High Wycombe factory of Hoover Ltd. supplied by the Electro-Chemical Engineering Co. Ltd. which is described and illustrated here was recently put into operation for the chromium plating of the steel covers on the Hoover steam-or-dry irons made at this factory. Since the shop itself was designed to deal with processes involving fumes, it is walled in to seal it from the remainder of the factory and air-conditioned for the benefit of those who work in it. In order to get the most light, there are glass windows round the sides and a glass ceiling admitting both natural and artificial light with walkways over the ceiling for maintenance purposes. The electric light fittings are above this glass ceiling to avoid corrosion.

Unimpeded floor space is obtained by taking all pipes and conduits to the side and, where possible, outside the walled-in enclosure. The floor is of acid-proof castellated tiling and the walls also have acid-proof tiles. A drainage system has been installed with neutralizing tanks in the factory yard.

The window framing is lead covered. All inside window ledges are sloping to stop people putting any objects on them, thus avoiding litter.

Process Details

The work is carried out on a flow-line production system. Outside the enclosure there is a degreasing tank, partially sunk to bring it to easy working height. From this, components to be treated enter the plating shop proper by a roller conveyor. The central feature of the equipment in the shop is the "Little Steve" automatic electroplating device (Fig. 1). This apparatus consists of a central carrier system operating above and between

Fig. 2. View of the cleaning side of the automatic line. In the right foreground are cold and hot water rinses and an operator is seen transferring iron covers from the rinse to a conveyor for subsequent drying and polishing.

a double line of tanks. The hanger-arms, which carry the workpieces, are of bell-crank form, and are mounted pivotally on small roller carriages that travel along a guide-rail. One limb of each bell-crank is provided with a radiused roller, which follows a cam-rail arranged parallel with the chain and guide-rail. Components placed on the hanger-arms of the cranks are thereby automatically lowered into, and raised from, the various solutions, as they are carried from tank to tank.

In operation, the component comes in from the degreasing vat and, having been loaded on to the central conveyor, begins its run through various tanks on one side of the Little Steve (Fig. 2), passing in turn through a cathodic clean, cold water rinse, anodic clean, cold water rinse, acid etch, cold water rinse, copper strike and two cold water rinses. It is then transferred manually to a semi-automatic copper plating tank (Fig. 3) for 22 min., where 0.0007 in. copper is deposited. It then enters a drag out, a cold water rinse and a hot water rinse and, having been dried and polished outside the enclosure, again makes the same circuit of Little Steve which it has already made once, but this time instead of going to the copper plating bath it is manually transferred to a semi-automatic nickel plating bath (Fig. 4) where for 16 min., it receives 0.0008 in. deposit of nickel.

The component is then passed through a drag out and a cold water rinse and is loaded on to the return side of Little Steve (Fig. 5) where it successively passes through another cold water rinse, the chromium plating tank, a drag out, a cold water rinse, a neutralizer and then cold and hot water rinses. The component is then off loaded and inspected.

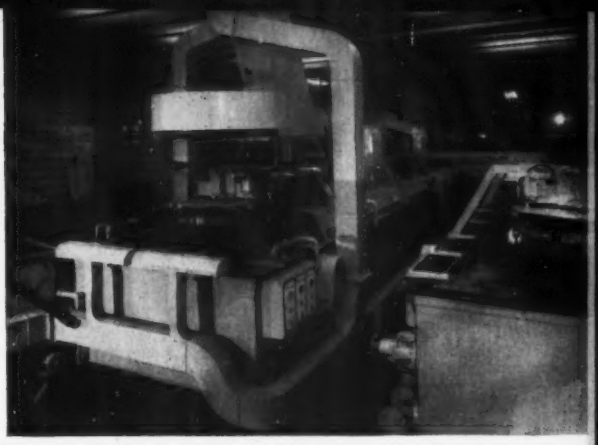
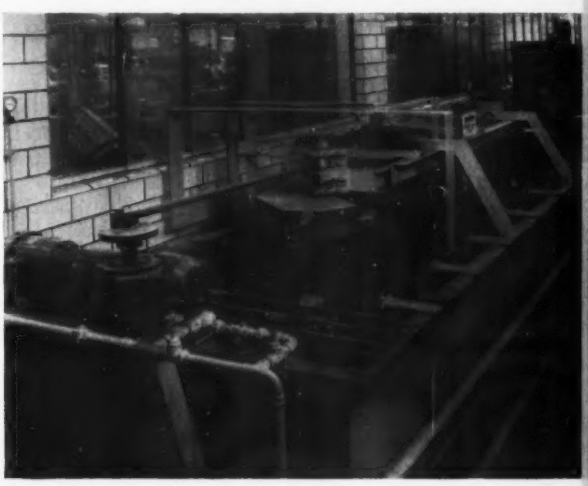


Fig. 3. The copper plating installation is on the left with the nickel line on the right.



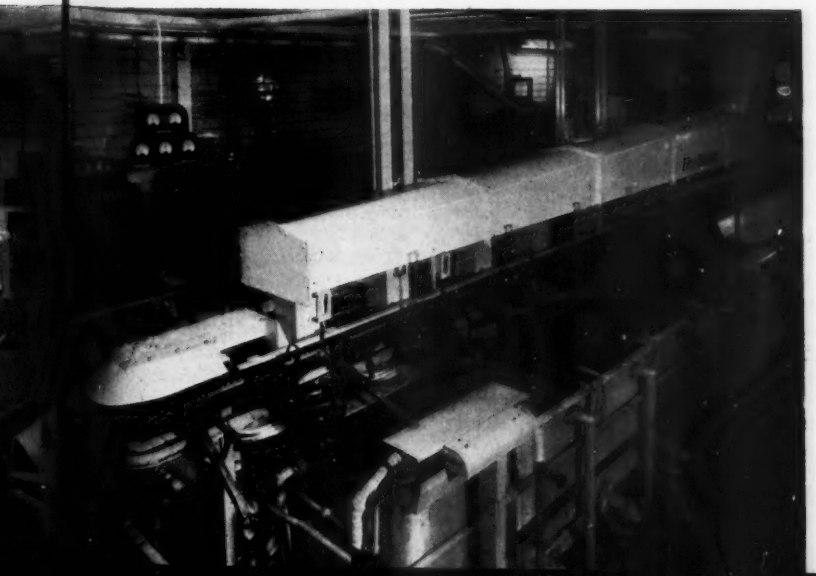


Fig. 4. (above) A general view of the semi-automatic nickel plating plant.

Fig. 5. (left) The other side of the "Little Steve" automatic line which is devoted to the chromium plating sequence.

A Quarterly Survey of some of the Features in Finishing Literature from Abroad

by **SCRUTATOR**

IF Sprowl Speichers[1] predictions prove correct, hot-dip aluminizing could provide a "new look" for cast iron. The process, which is simple to use and operates most satisfactorily on sand-blasted surfaces, produces bright, lustrous coatings which have properties similar to cast aluminium and which are particularly resistant to corrosion and high temperatures. They suggest that this increased protection will permit the use of less costly grey and malleable iron in applications now limited to high alloyed types.

Organic Finishing

Painting is unquestionably the most widely employed surface coating method for affording both protection and decoration to metal surfaces. In published information on this very important subject, however, the method of application all too frequently receives far too little attention and may simply be dismissed by stating "application is by brushing, spraying, dipping, flow coating or roller coating, etc." as appropriate. It is interesting to note therefore that in the last few months the American finishing journals have carried a number of articles describing industrial applications of the various modifications of spray painting.

Hot spray painting is of course not new and a number of American car manufacturers are using it to a limited extent. The first 100 per cent. hot-spray-painting installation in the U.S. automobile industry is now being installed at Somerville, Mass. by the Mercury Division of the Ford Motor Co. for painting the new Edsel car to be introduced very shortly[2]. The decision to use hot spray for both primer and colour coats followed a thorough investigation of the technique at the Wayne, Michigan plant where definite advantages were established. These included heavier film build-up and consequent reduction in physical effort as the required film thickness is produced with fewer passes, a reduction in overspray and reductions in wet sanding and paint consumptions of up to 25 and 35 per cent. respectively in some instances. A further modification of this technique is that of low-pressure hot spray painting which is described by Warren Beach[3].

Steam-spraying, in which superheated steam is used as a replacement for compressed air, was first introduced 9 years ago and according to Wagner[4] is now being successfully used by the U.S. automobile, household appliance, hardware, electrical equipment, railway and farm equipment industries. Paint savings for one railroad passenger car operation are claimed to be as high as 63 per cent. and at one refrigeration equipment manufacturers a figure of 20 per cent. is quoted. Additional advantages are better quality and appearance of the finish, more paint per pass and savings in thinners. Against these however, must be offset the necessity for special equipment, frequent cleaning of the guns and much closer attention to pressures and general coating conditions. Under the licensing arrangements the royalty for operating the process is 1 per cent. of the nett purchase price of the finishing material (including thinners) applied by steam spray.

Starr[5] has given a fairly detached description of the new airless spray rig at the El Segundo plant of the Douglas Aircraft Co. for the application of flat matt white paints. It is claimed that these can be applied via hoses up to 150 ft. in length without difficulties due to clogging and excessive pump wear etc. Furthermore, as the finishes can be deposited satisfactorily at distances of 10 ft. or so from the spray gun, the need for scaffolding is greatly reduced, a factor of considerable importance in aircraft manufacture.

Plating and Anodizing

Missel[6] has described techniques for the electrodeposition of chromium on the 5 per cent. Cr—3 per cent. Al, 4 per cent. Mn — 4 per cent. Al and 6 per cent. Al — 4 per cent. V titanium alloys. The cycle consists of cleaning, activation (this varies with the alloy) and plating. An order of adhesion comparable with that of chromium on steel is claimed and some work on the electrodeposition of copper on these alloys is also reported.

On the rather more academic side, Mason[7] has used toluene for the application of Archimedes principle to the determination of the real density of unsealed and water-sealed anodized coatings on aluminium. The percentage pore volume was also calculated from these figures. On 1100—

(*Continued in page* 400)

THE INSTITUTE OF VITREOUS ENAMELLERS

23rd ANNUAL GENERAL MEETING AND CONFERENCE IN CHESTER

Report of Proceedings and Works Visit

THE twenty-third annual general meeting and annual conference of the Institute of Vitreous Enamellers was held in the Grosvenor Hotel, Chester on October 3 and 4, 1957. Over the period nearly 200 members and guests participated in the technical sessions and social functions.

The whole of the first day was devoted to a visit to the works of John Summers and Sons Ltd. at Shotton where members were privileged to see all the processes from the blast furnace to the coating of the finished cold-rolled strip.

At the annual general meeting which was held on the morning of October 4, Mr. W. Thomas (Chairman of Council) presided. On rising to present his report on the year the Chairman expressed his pleasure at welcoming so many new delegates to the Conference. He hoped that the Conferences were continuing to meet a real need and attracting interest.

Dealing with the work of the Institute over the past year, Mr. Thomas first came to some resignations and retirements of members who had been connected with the Institute since its foundation. Mr. H. Whitaker, though remaining a member of the Institute, had resigned from the Council, feeling that he should give way to a younger man. He was a founder member and the Council regretted his departure and thanked him for all the work he had done since 1934. Another retirement was that of Mr. Alastair McLeod, who for many years had been chairman of the Publications Committee, which provided the papers for the Conference, and their sincere thanks were due to him. The Council hoped that he would maintain his connection with the Institute and had elected him as an honorary member. Finally, Mr. Fyfe-Smith would be leaving this country for two years, so that they would lose the benefit of his presence on the Council. The Council thanked him for what he had done on behalf of the Scottish section, wished him a happy and successful period abroad and would look forward to his return.

An important feature of the past year had been the change in the constitution of the Institute. Thanks to the tremendous amount of work done by the Development Committee and its chairman Mr. John Hooper, new Articles and Memoranda of Association had been produced which brought recognition for the Institute as a non-profit-making technical body and rendered it unnecessary to use the word " Limited " in its title. It had been necessary in the past for the Institute to deal with certain items which were partly commercial in nature. The Institute was a purely technical body and should not have to be concerned with anything having a commercial flavour. With the formation of the new body, the Vitreous Enamel Development Council, it had been possible to hand over to it the quasi-commercial work hitherto done by the Institute, principally in regard to raw materials. The Institute had always had a Raw Materials Committee, and during and after the war had negotiated with the Government on matters relating to the import of raw materials which were vital for the enamelling industry. That could hardly be regarded as a purely technical activity, and the Chairman was glad that it had been possible to hand it over to the new body. The thanks of all the members were due to Mr. John Hooper and his committee.

The Institute had organized two international conferences on vitreous enamelling in recent years, and, to follow up the work which had been done, consideration was being given by those concerned in the various European countries to the idea of setting up an international body which would look after the technical interests of vitreous enamelling, particularly by arranging international conferences, and which would correlate the efforts of the various bodies concerned. To that end a meeting was being held in Brussels in the near future to which would be invited representatives of the Institute and of its various European counterparts.

The committees and sub-committees of the Institute had done good work. The *Atlas of Defects* had been very well received, both in Europe and in America, and their thanks were due to

Mr. Biddulph for all that he had done in that connection.

A new development had been to secure the co-operation of the laboratories of certain firms, and one in particular, in the enamelling industry to carry out investigational work in conjunction with a sub-committee of the Institute on the effect of detergents on enamels. This was a most complicated problem. There was need for a standard test which could be adopted by the British Standards Institution for the effects of detergents on enamels. A great deal of investigation was required to ensure that nothing was put in a standard specification which would be open to criticism. If there seemed to be delay in publishing a detergent specification it was due to the need to get all the facts correct first.

Through the good offices of the President a scheme had been put to the British Iron and Steel Research Association for work to be done on interfacial reaction between enamels and steel. The matter was still being considered, but it was hoped that the Director of BISRA would view it favourably.

In the Minutes of the previous meeting there had been reference to the apprenticeship scheme, and he would like to emphasize the great advantages which employers could receive by interesting their younger employees in this scheme. Three or four apprentices had now gone through the whole scheme and ended their indentures. The industry badly needed thoroughly trained young men.

The summer school at Droitwich had been, he thought, the most successful which the Institute had yet held, and their thanks were due to those who had done so much to make it a success, and particularly to Mr. J. H. Gray, the chairman of the Education Committee.

In conclusion, the Chairman thanked the Chairmen and members of the committees and sub-committees, who gave up their time to do the work which resulted in the various reports published by the Institute from time to time, and the Secretary, Mr. J. D. Gardom, and his staff for the work which they did for the Institute.

In the absence, abroad, of the Hon. Treasurer, Mr. W. S. Grainger, the financial report was embodied in the Chairman's report and both were adopted by the meeting. A formal motion was then proposed by the president, Mr. C. R. Wheeler, C.B.E. for the election of Mr. W. T. Wren as president-elect of the Institute for the ensuing year. This was seconded from the chair and carried with acclamation.

Institute Awards

The Chairman expressed his regret that no entries had been received for the Whittle competition and hoped that the younger personnel of the industry would submit entries for this award during the coming year. However, he was pleased to be able to report that on the unanimous recommendation of the Library and Publications Committee, Council had awarded the W. S. Grainger Medal to Mr. S. H. Ryder for his paper on "Current Mill Room Practice."

The result of the ballot for the election of three members to fill vacancies on the Council was next announced, the elected members being Mr. J. Hooper, Mr. T. J. MacArthur and Mr. W. Thomas.

Following the annual general meeting the first technical session of the Conference was held at which Dr. W. H. F. Tickle and Mr. D. A. Winton discussed the subject of "Continuous Surface Pretreatment Processes at Shotton with particular reference to Nitec Sheet for Vitreous Enamelling." This discussion was augmented by the showing of the film "Zinc Controls Corrosion." At the second technical session a paper was presented by Mr. J. A. Clark on "Abrasion Resistance Tests." Following Luncheon the three technical sessions in the afternoon were taken up with papers on "Enamelling of Aluminium" by A. Biddulph, "The Application of Vitreous Enamel by the Electro-Static Process" by S. Hallsworth, and a discussion forum on "Enamelling in Architecture" introduced by E. Mackasek and T. J. MacArthur.

In the evening the Conference culminated in a reception by the President and Chairman of Council and their ladies, which was followed by the Annual Banquet. Among the official guests entertained by the Institute at this function were the Rev. E. J. Lawson, Mayor of Chester, Mr. S. W. Vickery, Chairman of the Vitreous Enamel Development Council, who proposed the toast of the Institute and the enamelling industry, the Rt. Reverend Gerald Ellison, Lord Bishop of Chester, who responded to the toast of the guests, Mr. J. W. G. Pedder, Chairman of the Vitreous Enamellers Association, and Mr. C. E. Ramsden, president of the Society of Glass Technology. The Banquet was followed by dancing.

Overseas Review

Continued from page 398)

H16 aluminium alloy the density of an unsealed sulphuric acid anodized coating was 2.96 with 15.8 per cent. pore volume. The corresponding water-sealed density figure was 2.65. Similar coatings on 2024-T3 alloy had lower densities but higher pore volumes.

References

(1) *Iron Age*, 1957, **180**, (6), 87.
(2) *Iron Age*, 1957, 180, (5), 104-105.
(3) *Products Finishing*, 1957, **21**, Aug., 42-43.
(4) *Organic Finishing*, 1957, **18**, (8), 4-7.
(5) *Organic Finishing*, 1957, **18**, (6), 4-6.
(6) *Metal Finishing*, 1957, **55**, (9), 46-54.
(7) *Metal Finishing*, 1957, **55**, (8), 55-57, 67.

Enamelling Conference Delegates see

THE PRODUCTION OF ENAMELLING and ZINC-COATED STEEL SHEETS

on visit to the Shotton Works of JOHN SUMMERS and Sons, Ltd.

ALTHOUGH John Summers have been rolling sheets at Shotton since 1896, and prior to that for nearly 40 years at Stalybridge, it was not until 1953 that the culmination of 100 years of progress was reached in the establishment of a fully integrated plant when the first pig iron was produced at Shotton. Leading up to this development was the decision in 1937, followed by the installation in 1939, of the revolutionary continuous wide hot and cold-strip mill to replace the old hand-mill method of rolling, thus permitting the production of steel sheets of greatly enhanced quality.

From the vast works on Deeside, now occupying 530 acres, employing over 10,000 persons and handling 7,000 or more main-line wagons per week over its 76 miles of works railways, steel sheets are despatched daily to manufacturers of office furniture, motor-cars, refrigerators, washing machines, kitchen cabinets, and a host of other things. Thus, a large proportion of these sheets are formed into consumer goods which require a high degree of surface finish. The surface finish of the steel sheet as it leaves the works at Shotton is, therefore, of vital importance and in this respect John Summers have spent much time and effort in studying and developing methods for improving the surface treatment of sheets, not only those for enamelling purposes, but also those coated with zinc. In addition to these " special " sheets the improvement in surface finish that has resulted in the ordinary " black " sheet from the continuous method of rolling, is appreciated both by the sheet steel fabricator and also the user. Together with the co-operation of the paint industry, these advances in the technique of sheet steel manufacture have resulted in a much superior finish for the many products made from this type of steel.

The production story behind these sheets of steel, whether delivered in packs or in giant coils, begins with coal and the ore from which the iron is smelted.

PROCESSING

Raw Materials

All the raw materials for the iron-making section of the plant, ore, coking coal, and limestone, arrive by rail. Train loads of foreign ore, from North and West Africa, Newfoundland and Sweden, to mention only a few countries, arrive from Bidston Dock, Birkenhead : after unloading from the steamer at the dock, the ore is sent in special wagons of 65-tons capacity to Shotton. On arrival at the works these wagons are shunted to the ore bench.

The ore bench is, in effect, a long series of hoppers under a railway track, specially installed for rapid unloading. Trains are run on to the track and their contents discharged quickly by opening the bottom doors of the wagons. The ore falls into the hoppers, and is conveyed by belt to a crushing plant, which breaks it up into pieces uniform in size, and separates the fines or dust.

The ore is then taken, again by belt, to the stock-yard which can store more than 200,000 tons of ore at any one time, or to the blast furnace for immediate use. Fine ore passes to the sinter plant for treatment prior to its use.

Coal comes from Yorkshire and South Wales, and limestone from North Wales and Derbyshire. The contents of the coal wagons are tipped on to belts carrying them to the storage heaps, where they are blended. The coal is stacked in 5 banks each holding about 14,000 tons and 1,000 ft. long.

This method of stocking and blending in banks is thought to be the first application of this type of plant for the purpose. Its advantages include excellent blending, the elimination of blending bunkers, and the steady rotation of coal stocks.

Coke Ovens

The blended fuel is passed by conveyor belt to two 5,000-ton coal service bunkers. From these it is fed into four batteries of 44 coke ovens each, which produce about 16,000 tons of coke per week.

In addition to the coke from the ovens, gas resulting from the conversion of the coal is most important, and is treated in the by-product plant. After cooling and cleaning, and treatment for the removal of ammonia, tar and benzole, the gas goes to a waterless gasholder, of 1,000,000 cu. ft. capacity, for use at the ovens, steel furnaces, soaking pits and annealing department.

Full use is made of these by-products. It may be of interest that the ammonia, in the form of

sulphate of ammonia, is used in the manufacture of fertilizers, tar is consumed in the works for heating the steel furnaces and benzole is further refined for use as motor-spirit.

The surplus gas not required for burning in the works, is passed to the Wales Gas Board for use in their North Wales " grid " system.

Blast Furnaces

Each of the two blast furnaces has an output of more than 7,000 tons of iron weekly, and can hold about 1,000 tons of burden of ore, coke and limestone.

The hot air or blast for the furnaces is provided by turbo-blowers in a blower house near to the furnaces, in which there are also two turbo-alternators, each of 12,500 kilowatts, producing electricity for all parts of the works.

The gas generated in the blast furnace is used for raising steam and for heating the coke ovens.

Melting Shop

The molten iron is conveyed in 75-ton ladles from the blast furnaces to the steel plant, and is poured into two hot-metal mixers each of 1,200 tons capacity. The molten iron is drawn off, when required, from the mixers and transferred to the basic open-hearth furnaces, of which there are seven of 200-tons and four of 240-tons capacity each fired with coke-oven gas and tar. The iron is then smelted along with scrap.

When the charge is ready it is run off into ladles and from these poured into the ingot moulds. These ladles, which can hold 210 and 250 tons of molten steel, are manipulated by cranes of 325-tons capacity.

The closest control is exercised, including frequent laboratory checking, at all stages of production over the charge. For enamelling stock, special care is naturally taken to ensure a low carbon and impurity content.

Slabbing Mill

The red-hot ingots, up to 12 tons in weight, from the melting shop, are placed in the soaking pits to be brought up to the requisite temperature for rolling in the slabbing mill. There are 23 soaking pits, either of the square Amsler gas-fired type, the round Salem gas-fired type, or rectangular types either gas or oil fired.

In the slabbing mill, the ingots are rolled into slabs about 12 to 15 ft. long, 4 to 6 in. thick, and up to 55 in. wide.

The slabs are allowed to cool in the slab yard, where they are subsequently inspected for surface defects. Any defects are removed by scarfing, carried out by means of special cutting torches.

Continuous Hot-strip Mill

Before rolling in this mill cold slabs from the stock yard are first charged into one of three re-heating furnaces. These furnaces oil fired and of the continuous pusher type, are 85 ft. in length and can each handle 60 tons of slabs per hour.

When heated to the correct temperature, the slabs are discharged on to rollers feeding the hot-strip mill, where the hot slab is now processed. This mill is of the 4-high type and consists of eight stands. The slab passes first through a vertical edger before entering the first three " roughing " stands. Finally it passes through the " finishing " stands where it is rolled down to thickness. For material required in the hot-rolled condition, excluding plate thicknesses, hot-rolled sheet is available at Shotton in 11 to 16 B.G. (0.1113 in. to 0.0625 in.). For sheet required as cold reduced, the " band " gauge for the hot-rolled sheet which is formed up into coil prior to further processing, varies from 0.07 in. for cold-reduced sheet with a finished thickness between 0.018 and 0.024 in., to 0.132 in. for 0.058 in. sheet and heavier.

Fig. 1. *Cold-reduction mill.*

Cold-reduction Mill

Prior to cold reduction, the hot-rolled coil is processed through the " pickle " lines, where mill scale is broken by a mechanical scale breaker and the surface is cleaned in acid baths. It then passes through a cold-water tank, a hot-water tank, a hot-air dryer and is oiled.

The coil is now conveyed to the cold-reduction mills. There are two such mills ; one a four-stand 56-in. tandem mill and the other an 80-in. reversing mill. Cold-reduced coil or sheet is available in thicknesses between 14 and 26 B.G. (0.0785 in. and 0.01961 in.).

The cold-reduced coil is then either cut up into sheets, or left as coil, and goes direct to the annealing furnaces where the requisite physical properties are attained by suitable heat treatment. For coils there are two slitting lines where the coils are trimmed to width and then re-coiled. For cutting up into sheets, there are two rotary shear lines. In these the coil is first trimmed to width and subsequently rotary sheared to length.

The annealing furnaces are of the Lee Wilson type ; there are 31 furnaces and 89 bases.

Finishing

The sheets or coils are skin passed (tempered) by cold rolling in four-high balanced mills to give the temper and elongation required for subsequent pressing operations, and to prevent stretcher-strain ; also to obtain the necessary degree of flatness and surface finish. Temper rolling, particularly, requires expert knowledge and experience, and the rolling operation, using alloy-iron rolls whose surface is controlled by a gas flame needs to be carried out with much care.

To facilitate operations, sheets when necessary are processed in multiple sizes and re-sheared at the final stage. Sheets are individually handled and inspected, branded and oiled for protection during storage and shipment. When required, sheets are supplied in the dry condition.

When material is shipped in coil form, the coils are tempered, oiled and packed.

The roughness of the sheet surface is important in the processing of sheets by users and also on the appearance of highly finished articles fabricated from them. Great attention is, therefore, paid to this property.

A surface roughness measurement instrument, the first ever installed in a mill department, has now been in regular use for several years. After each roll change in the cold-reduction mills and skin pass (temper) mills, the strip surface is tested.

By means of this instrument, very close control can be exercised over the degree of surface roughness. This is of much help to those subsequently engaged in applying finishing treatments to the sheet.

FINISHED SHEETS

Black sheets, both hot-rolled and cold-reduced, as mentioned earlier, are supplied by John Summers for very many diverse purposes, and many of the products are finished by painting and thus require sheets with the best possible surface finish. In this latter context, however, the sheets produced at Shotton for the vitreous-enamelling-industry and the sheets coated with zinc are probably of even greater interest.

Enamelling Sheets

In producing this type of sheet great care is given to the requirements of the vitreous-enamelling industry for sheets that will not reveal, during firing, faults due to incorrect steel composition, and also sheets with a surface finish that will give the strongest possible adhesion between the steel and the enamel.

Mention has been made earlier of the extremely close control that is exercised on the steel composition throughout all stages of manufacture, and particularly so during the later stages of the open-hearth process. The aim is to produce a steel with a low-carbon and low-impurity content. Should a cast not meet the rigid requirements in this respect, it is rejected as an enamelling-quality steel.

Within the general term of " guaranteed enamelling grade " there are the sub-divisions for " flat work ", " deep drawing " and " extra deep drawing." Sheets are produced in these categories depending on the forming requirements for the particular job in question.

It may perhaps be mentioned here that every sheet, including enamelling and every other grade, is produced to meet a given requirement ; there is complete identity from the original casting to the finished sheet. Hence there can be no large stock of finished material as might perhaps be imagined possible in a basic industry.

The production of enamelling-quality sheets from steelworks onwards through slabbing mill, continuous strip mill, etc., follows generally the processing described earlier. Special care is taken in ensuring that the sheets have the surface finish most suitable for receiving a vitreous-enamel coating.

Coated Sheets

Development in the production of coated steel sheets has made great strides during the last decade, particularly in regard to zinc-coated sheets. Two types are produced ; namely the continuously hot-dip galvanized sheet and the electrolytically zinc-coated sheet. Generally the former type of sheet may be used without any further treatment;

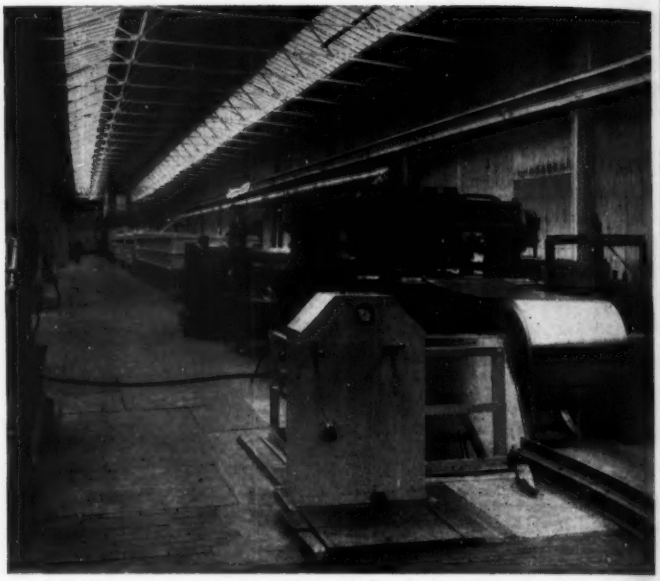


Fig. 2. General view of continuous galvanizing line.

the second type of sheet, sometimes referred to as a pre-coated sheet, is invariably used with a paint or some other type of finish.

Continuous Galvanizing Process

The " galvanized corrugated iron " sheet is one of the historical products of the sheet-steel industry and, as for other sheetmakers, it was for John Summers, for very many years, the principal type of sheet produced.

With the decay of the export market for this type of sheet and the introduction of continuous methods of rolling, the production of galvanized sheets by the old hand dip galvanizing process was rendered obsolete and a plant operating the continuous galvanizing process, the modern process for producing galvanized sheets, was installed at Shotton in 1937.

There are now three separate lines, and they are, in fact, the only lines of this process in this country at present in operation.

It will be recollected that in the hand dip galvanizing process, individual sheets are pickled, rinsed, dried and fed into the galvanizing machine in separate and quite distinct operations. In the modern process an endless coil of steel is passed through the galvanizing machine.

At Shotton, the coils are taken directly from the cold-reduction mill to the galvanizing plant. At the entry end to the latter plant the coil is decoiled and spot welded to the end of the coil preceding it. The coil then passes through a roller leveller and, *via* a looping or take-up pit, into the surface-treatment and annealing furnaces. In these furnaces, the coil passes at temperature through a reducing atmosphere of cracked ammonia which imparts to the coil both a deoxidized matt surface especially suitable for receiving a zinc coating, and the requisite metallurgical properties

Without contact with the air, the coil passes over rollers into the galvanizing bath and then onwards to the cooling train, the flattener, and the shear and the re-coiler.

No flux is used in the galvanizing bath and this, therefore, permits the presence of a very small amount of aluminium in the zinc. Aluminium inhibits the formation of the iron-zinc alloy, which accounts for about half the coating thickness in hand dip galvanized sheets ; the use of aluminium in the hand dip process is generally not considered practical because of reaction with the fluxes used. The alloy layer is very brittle, hence the general run of hand dip galvanized sheets can only be very moderately formed. Generally currugating is the maximum amount of deformation possible before the zinc coating begins to flake. On the other hand, the continuously galvanized sheet, with the very minimum of alloy layer, can be bent flat on itself, cold formed to the most complex profiles and even moderately deep drawn. Also important in this respect is the thorough cleaning, in an inert atmosphere, of the steel surface, which undoubtedly helps to improve the adhesion between the zinc and the steel.

Coupled with the remarkable forming properties of the modern type of galvanized sheet, is the uniformity of the coating thickness. Tests carried out by the British Iron and Steel Research Association indicate that coatings produced by continuous galvanizing are much more uniform in thickness

Fig. 3. (left) Strip coming out of galvanizing line.

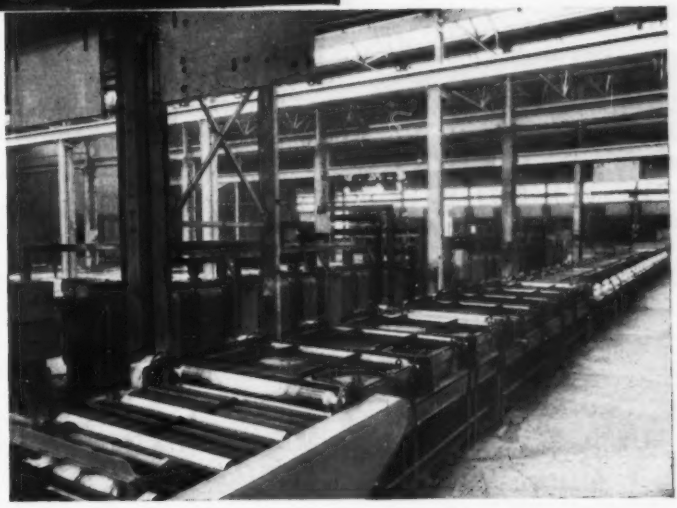


Fig. 4. (right) General view of electro-zinc coating line.

than those produced by the hand dip process. Thus, for a specified coating weight, the longest possible life is obtained with sheets produced by the modern process.

These two properties of formability and uniformity of coating have enabled galvanized sheet to be used for an ever widening number of uses. While the corrugated sheet is still made in quantity, the use of flat sheet or coil for railway coachbuilding, vehicle bodies, drums, refrigerator interiors, ventilation ducting, fan blades and the like, indicate how the scope of application of a traditional product may be revolutionized by the introduction of new methods of manufacture.

Furthermore, the supply of continuously galvanized coil, as distinct from sheet, permits the use of modern production techniques, thus helping to improve productivity in the fabricating industries.

The dimensions of galvanized sheets supplied from Shotton cover a wide range. In thicknesses from 14 B.G. (0.0785 in.) to 26 B.G. (0.01961 in.); with a maximum width of 48 in. for gauges heavier than 20 B.G. (0.0392 in.). In coil form, a maximum weight of 2½ tons is possible.

Concurrently with the development of these new uses for galvanized sheet, it was necessary to

investigate methods of welding in order to enable full utilization of modern production methods. After extensive trials, it has been found that with only comparatively small alterations to existing practice for uncoated sheets, these modern galvanized sheets can be spotwelded, resistance seam welded, gas welded, and carbon- or metallic-arc welded, and very strong welds result.

In some instances, the coating may be affected by the heat applied during welding, in the vicinity of the weld. Any such areas may easily be "touched up" by the use of zinc-rich primers containing 95 per cent. of zinc.

For most purposes, articles fabricated from galvanized sheets do not require any further protective treatment. However, for decorative reasons or to obtain yet further protection, paints such as those based on calcium plumbate, the zinc-rich primers and certain plastic resins, give satisfactory results when applied to newly galvanized sheet. No pretreatment other than the removal of grease and dirt is necessary.

Electro-zinc Coated Sheets

Although the modern hot-dip galvanized sheet can be formed more easily and more severely deformed than the old hand-dip type, there are, of course, limits to the amount of deformation it will stand. Also, it is most economically used in its natural colour. Thus for purposes where components are severely daep drawn and the completed article is required with a highly finished and coloured surface, a galvanized sheet is clearly an inappropriate type of sheet to employ.

As is well known, zinc is an excellent protective medium for steel. Thus, the desire to retain a zinc coating and yet supply a steel sheet that can be manipulated in the same manner as black sheet, has been behind the development at Shotton, during the last decade, of electro-zinc coated steel sheet.

This type of sheet has now been in production for 10 years and it is used for a wide variety of purposes, such as motor-car manufacture, washing machines, refrigerators, office partitioning, lifts, cranes and electrical equipment.

The advantages of electro-zinc coated sheet over black sheet include no deterioration during storage or during successive stages of manufacture, minimum cleaning prior to the application of paint or finishing treatment, protection of hidden parts where paint cannot reach — in fact some internal parts such as in partitioning do not require any painting at all — and an excellent basis for paint and one which prevents any creeping of corrosion under the paint film should the latter be damaged.

It is of interest that the zinc coating does not limit in any way whatsoever, the forming of the steel sheet, in fact, it seems to aid forming. The coated sheet may be deep drawn, spun, cold formed in exactly the same manner as black sheet.

The standard zinc coating for these sheets is 0.0001 in. in thickness, although both thinner and thicker coatings may be obtained if desired. These zinc-coated sheets are manufactured in the usual range of sheet dimensions, and also as thin plate, in several modern plating production lines. These lines are highly instrumented, thus ensuring very close control over the entire process and particularly on coating thickness which does not vary more than $\pm$ 10 per cent. anywhere on the sheet.

In order to obtain a proper steel surface on which to deposit the zinc coating, it is essential to have a surface which is thoroughly clean. Great care is, therefore, exercised in this respect and about two-thirds of the 200-ft. long plants are devoted to cleaning.

The steel sheets after rolling, annealing, cutting to length, inspection, etc., in the continuous strip mill, are delivered to the electro-zinc coating plant. The sheets on entry to the plating machine pass first through the degreasing and pickling solutions, which have spray rinses between, in order to bring the sheet to a laboratory degree of cleanliness. Both these sections are electrolytic with the sheet as the anode.

The pickling sequence consists of passing the sheets through a bath containing sodium orthosilicate, a wash and then through a further bath containing dilute hydrocloric acid, followed by a water rinse. The sheets are wiped by passing through flexible plastic or rubber lips.

After cleaning, the sheets pass immediately into the plating section before an oxide film can form, and as a result of the very close control of speed and current a very uniform coating of zinc is obtained.

In the electro-plating bath proper, the sheets form the cathode and are guided by rollers through the electrolyte at room temperature. The zinc anodes are of about 99.9 per cent purity. If both sides of the sheets are to be coated at the same time, two sets of anodes are required, one above and one below the sheet. The reason for this is that zinc deposits only on the surface of the sheet adjacent to the anode. One result of phenomenon is that sheets can be produced with coatings of different thicknesses on each side. This is very useful should one side of a sheet be exposed to more arduous conditions, and a number of industries take advantage of these differentially coated sheets.

The current used for deposition depends upon the speed and coating thickness required. Capacity up to 40,000 amp. at 5 to 6 volts is available.

After passing through the plating section, the sheets then enter a further bath where they are subject to a chromate rinse. Should the customer

require it, sheets may be obtained in the phosphated condition.

The operation of the plant is regulated from a central control desk. To drive the sheets through a plant, there are three main drive motors, synchronized and coupled to one mainshaft running the length of the plant and actuating the drive rollers.

Air pressure is provided to ensure uniform pressure on all rollers, rendering unnecessary any lateral guides to keep the sheets from wandering. The cells holding the various solutions are situated between each pair of rollers.

A comprehensive pumping system allows ample capacity on each pump, so that if one breaks down, the alternate pump on another plant can take over the work of two. Solutions are heated by steam coils in tanks below the main frame of the plant and are controlled by thermostats and motorized valves.

At entry of a sheet to the plant, if a defect is noticed, the faulty sheet is rejected through a pair of rollers on the end of the feed table. Again at the discharge end, the inspectors have time for adequate examination of the finished product.

As for galvanized sheets, extensive research has been conducted into the fabrication of Zintec and particularly into methods of joining, such as welding. In general Zintec can be welded without difficulty but with little difference to the practice employed for black sheet. For painting, also, as described below, there has been much research activity.

RESEARCH LABORATORIES

Highly qualified staff in extensive and well-equipped research laboratories are engaged not only in striving continuously to improve the quality and methods of production of all the various types of sheet produced at Shotton, but as has been mentioned, the methods for using the sheets.

These research facilities are freely made available for the sheet users and considerable advantage has been taken of them, particularly in regard to painting. In this respect, John Summers are possibly unique as a steel firm in possessing a paint laboratory where research is carried out to determine those formulations of paint which give the optimum performance as regards adhesion and durability when applied to Summers' sheets. There is very close collaboration with paint manufacturers and there is no doubt that this work is of inestimable benefit to the users of sheets.

In addition to a welding laboratory including highly instrumented machines of modern design, there is also, of interest to the user, a laboratory for research into vitreous enamelling. This contains a frit mill, together with thermostatically controlled pickling, rinsing and neutralizing baths, and spraying equipment. In this laboratory it is possible to test the suitability of various types of sheets and frits, particularly with regard to the goal of a one coat-enamel.

FUTURE DEVELOPMENTS

With the increasing demand, and consequently output, for coated sheets of all types, the final stages in the metamorphosis, begun perhaps with the installation of the wide strip mill, of the great Works by the River Dee from a craft industry to one relying more and more on technological skill and knowledge and laboratory control, is reaching completion. Like the aircraft, chemical and electrical industries, new products are first evolved in the laboratory, rather than on the shop floor, and are designed to meet specific requirements of industry. Particularly so is the new coated sheet, known as " Stelvetite," the production of which on a commercial basis has just been announced.

Stelvetite, which consists of polyvinyl chloride sheet bonded to steel sheet so successfully that it can be bent, formed, deep drawn etc. without the P.V.C. parting from the steel, will enable industry for the first time to take commercial advantage of a material possessing the properties of strip-mill steel sheet and the corrosion resistance, colour and appearance of plastics. Manufacturers will thus have a material which does not require any further finishing. Furthermore, production costs will be decreased as Stelvetite does not require any maintenance ; its use is thus likely to lead to widespread economies.

While this material will undoubtedly have some influence on the extent to which other materials are used, it would seem more likely to lead to an extension of the use of steel sheet possibly into uses where it has not so far been employed at all, rather than render some forms of sheet absolete. That this is the view of John Summers is exemplified by the continuing extension of the production facilities for all types of coated sheet and also the development work proceeding on coated steel for enamelling. This latter type of coated sheet, consisting of enamelling-quality steel base coated with a nickel flash and a protective zinc coat brings together the enamelling sheet manufacturing and coating facilities at Shotton.

Trials with this sheet, which has as yet only been produced in limited quantities, indicate that it may provide the answer to an easily worked and relatively cheap sheet which will permit the application of a single-coat enamel.

The zinc coating which protects the sheet from deterioration during storage and fabricationin the same manner as for the normal electro-zinc coated sheet, may be pickled off in a fraction of the time necessary for pickling ordinary enamelling sheet. After pickling, the nickel surface is ready for enamelling, thus eliminating the necessity of a nickel dip.

A Survey of ABRASION RESISTANCE TESTS for Vitreous Enamels

by J. A. CLARKE

A Paper presented at the Annual Conference of the Institute of Vitreous Enamellers, Chester, October 3 and 4, 1957.

IT is intended in this paper, to review some of the methods which have been investigated in an attempt to produce a suitable standard abrasion or scratch resistance test for vitreous enamel.

This immediately poses the question — what is required, a test for abrasion resistance or for scratch resistance ? By the latter, one would think of a purely surface condition, in which the glaze only is destroyed, whereas with the former, the loss of a considerable amount of enamel below the surface is envisaged.

In many normal domestic usages, as for example, drawing saucepans over a cooker hob, using a knife on a table top, sliding crockery on a draining board, the emphasis would definitely appear to be on scratch resistance, since sharp points are undoubtedly involved in all the cases cited, and these points would cause scratching of the surface, as opposed to sustained abrasion of the sub-surface layers. Furthermore, once the surface is scratched, the appearance of any article is seriously impaired, and what happens subsequently is of little account, except in certain very specialized cases.

These considerations tend to lead one to the view that the aim should be to measure the resistance of the surface to scratching, not the resistance of the enamel layer to abrasion.

A further point in favour of this hypothesis is that, generally speaking, the apparatus required to assess scratch resistance would be likely to be less complicated and costly than that required for assessing abrasion resistance.

Having thus rather "begged the question," there follows a summary of the results of an investigation carried out by the author some time ago, together with a survey of the methods used, and results obtained by other workers in the same field — using both scratch and abrasion techniques.

The first test to come to mind is, of course, the one using mineral powders arranged according to Moh's Scale, and listed in B.S.1344. This was rejected as being quite unsuitable, mainly due to the fact that it is not sufficiently selective. Most enamels are passed by one powder, and failed by the next — virtually no gradation of enamels is possible by this method.

Before a lot of new ground was broken, it was considered advisable to investigate the methods used by the paint industry, to see whether any of their tests could be adapted to vitreous enamel. There appeared to be three tests in general use.[1] The first of these was an apparatus in which a fixed metal needle makes a scratch, the test-plate being drawn along underneath. The point of the needle is a spherical steel ball, usually 1 mm. in diameter, and the needle can be suitably loaded. Failure occurs when the ball completely penetrates the layer. If one tries to test enamel with this instrument, the needle merely slides over the surface when any normal load is applied, and the apparatus was found, for this and other reasons, to be quite unsuitable for use in the enamelling industry. The second was the Sward Rocker, or one of its variations. In this type of apparatus, one counts the number of oscillations of a circular rocker between given amplitudes, the figure obtained being a measure of the hardness of the surface. Since plate glass is used as a standard surface to calibrate this instrument, it is at once obvious that little differentiation could be expected with vitreous enamels. Other factors also preclude its use as a test in the enamel industry.

The third was the Taber Abraser. This consists essentially of two abrasive wheels, capable of rotation, which are pressed against the surface to be tested. The sample is clamped to a turntable, which is then rotated. This causes the wheels to rub against the specimen, and the loss in weight obtained after a specified number of revolutions is a measure of the abrasion resistance. Work was not carried out with this apparatus, as it was considered to be unsuitable for testing enamel, but recently, Ashby and Nicklewski presented a paper to the Institute of Vitreous Enamellers[2], describing an investigation carried out with the Taber Abraser. It would appear from the discussion following the presentation of this paper, that while the Taber Abraser is a valuable research instrument, it is not entirely suitable for use as a standard test.

In an endeavour to try and simulate service conditions, the author developed a fairly simple

abrasion machine. This consisted basically of a metal " rubber," of known area and weight, giving an initial minimum load of 20 gm. per sq. cm. It could be further loaded to a maximum of 250 gm. per sq. cm. Selvyt cloth, or any other suitable material could be attached to the " rubber," the cloth then being impregnated with any desired abrasive. The " rubber " was driven back and forth by an eccentric drive from a constant-speed motor, so that there was no variation in speed with increasing load. The speed was approximately one complete back and forward stroke per second. The length, and hence the speed, of the stroke could be varied. The plate was clamped in a position underneath the " rubber " during test.

A large number of experiments was carried out, using many different abrasives, *e.g.* Selvyt cloth impregnated with silica, aluminium oxide, Carborundum, etc., in many different grades of fineness. Various types and grades of emery cloth were also employed. In all cases tests were carried out both wet and dry. All the above materials were used with different loads, and for varying periods, but the results obtained were in no way suitable for a standard test. Generally speaking, if one enamel was attacked, all other enamels tried were also attacked under the same conditions, and in some cases, contrary to service experience. A big difficulty was assessment of results — visual inspection seemed the only solution. It was at one stage hoped that a " go or no-go " type of criterion might be adopted, but this too, proved untenable. For these reasons, the test was discarded.

As this appeared to be further evidence against the use of abrasion testing, work was then directed towards the evaluation of methods using diamond points for the estimation of scratch resistance.

The apparatus used for much of this work was as follows :—

Two parts were involved, the first part consisting of a brass block, cut out on the underside to form two parallel runners, enabling it to slide smoothly over the surface to be tested. It was found advantageous to cover these runners with felt to prevent any possibility of subsidiary scratching. A hole was drilled vertically through the centre of this block, to accommodate the stem of the second part of the apparatus. This stem could thus move vertically, but not horizontally. The bottom of the stem contained the diamond point, and on the top was fixed a small circular plate, used for carrying weights, thus allowing the load on the diamond to be varied.

In use the apparatus is laid on the enamelled surface, and, guided by a straight-edge, is passed over the test area. The load is increased by 50-gm. increments, and the above procedure repeated till a continuous visible mark is obtained. The assessment of the appearance of the scratch is difficult with light coloured enamels — an indicator is required. It was eventually found that the best method was to apply a solution of a dye, such as Methyl Violet, to the surface, before test, and to perform the test with the indicator *in situ*. The criterion was that a continuous line be produced. The only problem involved in the use of an indicator *in situ*, is whether the indicator lubricates the scratching mechanism. If this is in fact the case, it was assumed that, for all practical purposes, the effect would be the same in all determinations.

This method showed a great deal of promise, but unfortunately, some drawbacks were encountered. The shape of the diamond, and its alignment, were found to be of great importance, and thus it was found that while any one diamond would differentiate between the members of a series of different enamels, correlation could not be established between different diamonds. It is pertinent to note, however, that a series of enamels was always placed in the same order by every diamond tried, but that the loads required for the same enamel were different. It may be possible to arrive at some factor which would overcome this problem, particularly if diamonds cut very accurately to a predetermined shape were employed. Work with this type of diamond was, unfortunately, never completed.

It is interesting to note in this connection, that Morriss, as recorded in the I.V.E. Whittle Medal paper of 1951, worked on similar lines. The only substantial difference between his method and the one outlined above was the production of the scratch. Whereas in the former method the diamond is moved over the test-plate, in the latter, the plate is moved along underneath a fixed, and suitably loaded diamond point. The indicator — ink — is also used *in situ*. The findings were very similar to those recorded above. Morriss, however, overcame the variation between different diamonds by reference to a standard enamel plate, and claims that results can be expressed by the formula :—

$$\text{Scratch load} = \frac{\text{Load required to scratch test plate}}{\text{Load required to scratch standard}}$$

Results are then said to be of the order of $\pm$ 5 per cent. accuracy, with any diamond. This, if it can be substantiated, would seem to overcome the main objection to diamond scratch testing.

In a private communication to the author, Lawrence described a method in which an attempt was made to assess scratch resistance by measuring the width of a mark produced by a diamond under standard conditions. Briefly the diamond was fixed to a carriage capable of running down an

inclined rail system. This, by gravity, imparted a fixed speed to the diamond. By a suitable arrangement of cams, the diamond was lowered on to the test plate for a given run, and subsequently raised again. By this method, a standard reproducible scratch could be obtained. Several measurements were then taken along the length of the scratch, and a mean value of these was used as a measure of the resistance. Unfortunately, as is usually the case with diamond scratches, the marks produced were very ragged, and it was difficult to arrive at an absolute value. Though it was felt that this was a valuable research instrument, it would not be suitable for a standard test, due in the main to the difficulty of assessing scratch width which would occur between different operators.

In a similar vein, the author had an opportunity of investigating a micro-scratch apparatus. Here also, the raggedness of the scratch made any accurate measurement of scratch width impossible. In some cases, in fact, considerable overlapping occurred. The wider parts of scratches on resistant enamels were often larger than the narrower parts on poorer enamels. These considerations therefore ruled out this method.

It may be interesting to note in passing, that this apparatus was also capable of doing micro-hardness tests, in which a diamond pyramid was pressed into the surface under test. The size of the mark produced was taken as a measure of the hardness. Trials were made of this method also, but again, no conclusive results could be obtained.

This paper would not be complete without a discussion of the American P.E.I. Test for abrasion resistance.[3] In this test, a fixed test-plate is allowed to oscillate, causing a charge of steel balls, felspar and water to abrade the surface. The gloss of the specimen is measured before and after test, the difference being used as a measure of the attack. The method is claimed to be reproducible and to give results well in accordance with conditions observed in service, and is of course, widely used. It is, however, dependent on several factors, perhaps the most important being the availability of a given grade of felspar. It is important that this is exactly reproducible, or otherwise the test is valueless. Second, standard glass plates are required for calibration. Third, the apparatus, together with an instrument for measuring gloss, is quite expensive, and would perhaps be beyond the reach of many small enamellers.

There is some evidence, as yet unpublished, which suggests that good correlation has been obtained between results from the P.E.I. tester, and those from a diamond scratch instrument. This, seemingly, is further evidence in support of the development of a relatively simple scratch test, particularly if further work confirms these rather early findings.

Finally, mention should perhaps be made of an abrasion resistance test which has received little publicity, but which may conceivably offer some prospect. In this method, carefully graded steel grit — similar to that used in shotblasting — is allowed to fall by gravity from a pre-determined height, and at a controlled rate, and impinge on an inclined enamel surface. Limited experiments carried out using this technique showed that a " go or no-go " test was not a possibility, but perhaps some results might be achieved if a loss of gloss measurement was incorporated as a criterion. The method might well deserve further investigation as to its suitability for a standard test.

It is apparent that the question of abrasion testing is still in an impasse. Provided that abrasion takes place only at the surface, and is not allowed to proceed to the sub-surface layers, similar results can seemingly be obtained whether scratch, or abrasion tests are employed. Under these conditions, abrasion might perhaps be regarded as a " multi-scratch " phenomenon, rather than by its conventional meaning. The main difficulty would seem to be to decide when the surface ceases to be involved. There appears to be no doubt that the properties of the sub-surface layers are quite different from those of the surface, and as only in exceptional cases would resistance of the former be required, the emphasis should be placed on scratch or " multi-scratch " tests, as opposed to deep abrasion. There would be less likelihood of ambiguity if one scratch is taken, rather than a very considerable number, where repeated coverage of the same spots might well bring sub-surface resistance into play.

The main conclusions to be drawn therefore, are that while both scratch and abrasion tests can, and are being used to evaluate the abrasion resistance of vitreous enamels, the problem of producing an absolute standard still looms large on the horizon. All the methods used have their drawbacks in one way or another. From the point of view of cheapness and simplicity, it may ultimately be worth while to try and develop further a diamond scratch apparatus, even if the diamonds have to be specially prepared and individually standardized, since whatever method is finally adopted, some form of standardization appears inevitable.

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Discussion

DR. B. K. NIKLEWSKI said that the question of the abrasion resistance of enamels had been rather neglected for many years, but it was important, for parts of domestic appliances such as cookers and table tops, and also for some special industrial applications of enamel such as chutes for coal and ores, to develop a hard enamel having good abrasion resistance. Unfortunately in this country there was no standard procedure for measuring the resistance to abrasion and scratching. He was chairman of a sub-committee which had as its object the study of the problem in order to prepare a new standard. They had tried various methods and had found that it was extremely difficult to obtain reproducibility of results. Using the diamond test put forward by Laithwaite the results could not be repeated when using another diamond, so that the committee did not feel able to put forward tests developed on the basis of the diamond test.

What the committee had done, therefore, had been to decide to follow the easy road and imitate to a certain extent the P.E.I. test which had been accepted in America for many years. The difficulty was to produce apparatus which would be simpler and cheaper but which would work with the same precision as the American apparatus, which was elaborate and expensive. It should be possible to produce some kind of standard if there was a simpler arrangement of that kind which could be used by enamellers. One difficulty was to measure the loss of weight, but, from the papers which had been published on this matter, it would appear to be possible to assess the beginning of the wear of the enamel by careful weighing of the samples.

With regard to the loss of weight with time, there was a curve which would be specific for each enamel, and the abrasion of the surface and sub-surface was represented by a curve. The rate of the abrasion changed suddenly when the surface finished and the sub-surface began to be abraded. It should be possible to devise a simple apparatus for measuring loss of weight. The development of a system involving the use of special diamonds would probably require a great deal of research, and so it had been regarded as preferable to follow a road along which the Americans had already had some success.

Mr. Clarke had said a good deal about some work which had been done. It was a pity that this work had not been published. It was important to publish figures, because otherwise a great deal of experimental work might be done and then lost and that should never be allowed to happen. Figures should always be published when they were available. Was there any possibility of publishing the results of the work to which Mr. Clarke had referred ? That would be very valuable, whatever the results were.

MR. CLARKE said he understood that all the laboratory records had unfortunately been destroyed, so that the figures relating to the tests in question would no longer be available.

MR. A. W. MURDOCH said that when he read the paper he had been reminded of a paper, he believed of German origin, which he had read some time ago and which described an investigation comparing the wear resistance in service of two enamels with their chemical corrosion resistance and scratch resistance. Of these two enamels it had been found that one, apparently, had a good service life, and the other was considered to have failed, in that it became dirty very quickly and was difficult to clean. It had been found, however, that these two enamels had approximately the same chemical resistance to a series of chemical corrosion tests, and also the behaviour in the scratch resistance test, which had been done with a diamond, had been similar in regard to the weight taken without giving a scratch.

There had been an investigation to find out, therefore, why one enamel had failed and the other had apparently been successful. It had been found, on examining the scratch, that on the one which had passed it was a smooth, regular scratch, while on the one which had failed it was irregular and rather difficult to define. The surface of the enamel had then been examined, and it had been found that on the surface of the enamel which was considered to be satisfactory the distribution of the opacifier in the enamel was homogenous and there was a regular bubble structure which was low. In the other enamel the bubble structure was much higher and the opacifier was irregularly distributed through the enamel surface.

A series of tests had then been done in the laboratory on cleaning the enamels, and it was found that when the surface was dirtied it took five or six times the amount of cleaning to clean the one which failed, compared with the other, and it opened more bubbles, so that it became dirtier more quickly. Perhaps, therefore, the scratch resistance might not give the relationship between service life and the actual figures obtained for enamels.

MR. E. W. B. DUNNING said that thirty years ago he had been responsible for bringing out the original Moh's scale of hardness test, but he did not want to give the impression that, because they had produced it so long ago, they thought that it should be retained now if there was a better test available. He was surprised that, although Mr. Clarke had dismissed the Moh's scale, he had not produced any evidence to show that this was so. It might be said that the Moh's scale tended to put the enamels all in one grade, but it might be

found in practical conditions that, when a test had been produced which divided them into different, finer grades, when they came to be used on the district they would get back into wider grades again, because if the scratching was by abrasive cleaning powders, and they all tended to be of the same kind of hardness, one would come back to the same kind of condition. They themselves had tried out the Laithwaite diamond test but had had to abandon it and go back to the Moh's scale of hardness test. It was difficult to see the scratches, but if the test was carried out in a darkened room with one electric light bulb, by turning the surface it was possible to see a lot of scratches which were not visible on casual inspection.

There were two kinds of abrasion : there was the cleaning powder abrasion, and there was that due to the movement of pots and pans and so on on the surface. Whenever the industry thought that it had produced satisfactory apparatus, it would be very useful to obtain some comparisons, and the North Thames Gas Board would be ready to carry out tests in their own laboratory with the apparatus related to district conditions. He felt that they were in a better position than anyone else to get the comparison with the district, because they knew where all the appliances went. They could go to the house and ask to see them, and they did so.

That was something which they were prepared to do. If a manufacturer produced two enamelled crown trays of which one was thought to be better than another, they would be prepared to buy 100 of each kind and put them in houses, leave them for a year, and find out in the end which was the better. That was the only practical way of doing it.

They had been doing tests recently on the ease of cleaning of enamel, which also involved the question of abrasion and of what were the best materials to advise the customer to use. It was all very well to tell the user to clean it when it was hot and to use hot soapy water, but if the hot soapy water did not get the dirt off it would be no use. They had been considering the use of wire wool for cleaning, and which gauges of wire wool would get the dirt off and not scratch the enamel. They had found up to now that something which contained some detergent and abrasive and wire wool seemed to be the most satisfactory.

Dr. Niklewski, commenting on what Mr. Dunning had said, remarked that it was true that some enamels were very hard and some were soft, but that after a time in use there would be no difference between the scratches produced in the hardest and those in the softest enamels. Probably the Moh scale would put them all in one bracket, but a tool was necessary which would show a difference between one enamel and another or no progress would be made.

An interesting fact about abrasion was that pots which were enamelled with the softest enamel would scratch the surface of the hardest enamel. Aluminium would also produce scratches, *i.e.* a surface with some aluminium oxide formed. The very softest enamels, without any sharp corners, would scratch extremely hard enamels. Why that should be so was not known, but glasses were very different in their structure, so that a good deal of research had to be done on this matter.

Mr. S. E. A. Ryder said that nearly always when this problem was discussed the cost of the apparatus was mentioned, and they seemed to fight shy of certain suggested methods because it was said that the apparatus would be costly and would be beyond the reach of the smaller enameller. In his view, that was not a good way to look at the problem. Probably two methods were required. Mr. Clarke had mentioned a standard method. A standard method need be only a " go " and " not go " method, and the Moh scale was quite simple from that point of view and would probably fully satisfy all the needs of the smaller enameller. For research and development work, however, something more elaborate was needed, and probably something quite different. For that work they ought not to fight shy of a little expense.

Mr. J. C. Bailey said that in the aluminium industry they had had cause to try to develop a method of measuring abrasion resistance in order to improve the anodic films which they had a habit of putting on aluminium, and they had come hard up against more or less the same problem as that now under discussion. It might be of interest to the meeting to know that a good deal of effort had been put recently into a development of one of the methods mentioned by Mr. Clarke, that in which an abrasive fell on the specimen ; but they had taken this much further and developed what was called the Schon test, which had been put out twenty years ago in Germany.

The essence of this test was that instead of allowing the abrasive to fall on the specimen it was projected against it under air pressure. The apparatus was very simple, consisting of an 8-in. glass tube of $\frac{1}{8}$ in. bore, surrounded by a wider tube which projected beyond it downwards on the specimen, which was mounted underneath at 45°. The abrasive fell down the outer tube in a controlled manner, and air under pressure came through the inner tube. The resulting abrasion resistance was measured in terms of the weight of abrasive required to remove the anodic film, and was expressed in terms of the weight of abrasive per micron thickness of film.

That apparatus was the only one which had been developed, and he had to admit that they were having just the same troubles with it as were encountered with other apparatus for the same

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FORUM ON ENAMELLING IN ARCHITECTURE

Introduced by
E. MACKASEK and T. J. MACARTHUR

Presented at the Annual Conference of the Institute of Vitreous Enamellers, Chester, October 3 and 4, 1957

EXPERIENCE IN THE U.S.A.

by E. Mackasek

THE subject of architectural enamelling is not new and it is therefore not necessary to repeat all that has been written about it up to now ; however the future needs consideration particularly as the field has great possibilities. In addition to technical problems it is necessary to discuss aspects, such as trends in curtain-wall design and the relationship between the architect and the enameller, the strength of competition and methods of meeting it, the dissemination of a knowledge of vitreous enamelling amongst architects, better specifications, (an important matter, because today there is no specification for curtain walling) and improved performance of architectural vitreous enamel. This also is a matter of great importance, because the peak of perfection as far as the service of architectural enamelling is concerned, has not been reached. There are other questions which could be added, but those mentioned above give some indication of the problems which are current and which should be given immediate attention.

Considering the history of architecture, the author believes that there has been no development which has caught the imagination of the architectural profession to a greater extent than the concept of curtain walling. The architect is, and always has been, conservative, interested in new ideas but unwilling to put them into effect until they have been proved. Changes in architectural practice, therefore, usually come slowly. Against this background, the spectacular upsurge of curtain walling seems almost incredible ; in fact it seems almost an emotional epidemic. Epidemics, however, are apt to fade away very rapidly, and it is necessary to consider whether or not this is a permanent trend.

The curtain walling concept, as has been pointed out in a number of magazine articles, is not new, and examples of it going back fifty years have been reported. It is difficult to understand why, if the concept is fifty years old, it has taken so long to bring it to fruition. Prototypes are apt to point the direction to be taken, but seldom give the answer. The history of invention shows that great inventions are frequently merely the synthesis of a series of minor or lesser inventions, and timing, as in other things, seems to be important. An idea may be ahead of its time. Fifty years ago there was little actual technical knowledge upon which to develop a curtain wall as it is understood today. There was not much information available even as late as 1950, because when the Porcelain Enamel Institute commenced research on curtain walling and appointed a very prominent architect, William Lescaze, as research architect, he reported to the Institute after a short period that it was not possible to make progress because there was a lack of information of a complementary nature on insulation, which was required. He recommended the setting up of a separate investigation into some of these matters.

It is possible that a curtain wall might have been developed earlier, using available materials and those which might have been developed by research at that time, but the final result would probably have been academic rather than real ; in other words, there was no real need at that time for curtain-wall development. Today the position is different, and the high costs of materials and labour make the curtain wall a practical proposition.

The curtain wall is considered to be a manifestation of a movement which has been going on for some time, a movement to industrialize building and manufacture building components in factories. The curtain wall is the most spectacular result of this industrialization, and in some ways almost a symbol of it.

The first research project of a comprehensive nature was the development by the Porcelain Enamel Institute in 1950 of the first sandwich panel, *i.e.* a thin panel, 1 to 1½ in. thick. The first use of this in the United States was for the Statler Hotel at Hartford, Conn. Curtain walling is almost new-born and must be considered as being at present in a very elementary stage of development. Critical appraisements of its virtues and defects have appeared in a number of architectural journals but one of the criticisms is that curtain walling is becoming stereotyped. In a recent issue of the *Architectural Review* 18 British curtain-wall systems were shown, of which 17 are alike in that they show the window-wall construction in which there is an emphasis on the mullion system. That need

not necessarily be the case ; the author as a result of conversations with Italian architects and others, has found that they do not agree with it and are working on different plans.

Another criticism is that modern architecture is too flat and monotonous and the whole concept of a wall is changing. A wall is to a building what the skin is to the human body ; it must take care of many functions which formerly were not ascribed to it, such as heating and air conditioning. All this means that what is now being made as curtain walling will change very rapidly, and in fact this change is already apparent.

What then, is the relation of the enamelling industry to the architect ? There will be changes in the curtain wall, and the panel design will also change and must be integrated with the architecture. Who is going to design the new types of panel, the architect or the enameller ? It should be the architect, but the architect today has so many problems, and is concerned with so many new things which are coming on the market, that he tends to place the onus of responsibility onto the enameller who therefore, has to know what is going on and must change his tactics or design to meet what the architect wants, a major task for the enamelling industry.

Another task for the enameller is to spread the idea of or disseminate information about the qualities of porcelain enamel. A start has been made, but there is much more to be done. In recent architectural journals there has been some discussion on curtain-walling materials in which architectural vitreous enamel has been discussed, and some of it is very interesting. For instance, the *Architect and Building News* recently discussed pregalvanized steel sheet, coloured glass, and vitreous enamel on steel. It was stated that the second was an obvious choice, although the colour is restricted, and that porcelain enamelling is promising if only the cost could be reduced and the difficulties of waviness and distortion overcome. It pointed out that there are many vitreous-enamelled signs which are in excellent condition after half a century, other than blemishes caused by mechanical damage, the main disadvantage of vitreous enamel. The *Architectural Review* has also stated that vitreous enamel is a good material, *but*, and the " but " indicates that it is not considered to be a very strong material. It is apparent that the true facts are not known ; it is not appreciated, for example that enamels have been improved, so that they can do jobs today which formerly they could not do. Unfortunately, most architects think of vitreous enamel in terms of holloware such as was on the market 25 years ago. and it is not an easy task to change this view.

As regards competitive materials, probably the material most widely used for infilling panels has been glass, and it is interesting to consider the architects' opinions of glass curtain walling. Users have reported that it is a good material and no troubles have been experienced with it, but the author is very sceptical, about this but can understand their reasoning. The subject was dealt with in an excellent paper to the British Architects Conference by J. G. S. MacVeigh, who said that experience of some kinds of glass panels and some ways of using glass as facing and curtain walling is such as to warrant his including the material in the category of unsuitable. This applies only to certain kinds of glass in certain circumstances. In a number of buildings panels have cracked to such an extent that one architect was prompted to admit that although his client was not put to any expense, because the manufacturer replaced the panels free of charge, he nevertheless became rather tired of having no wall ! That was not surprising, because in this case some 300 panels broke. As for aluminium, it is felt that anodizing increases the cost, nor is aluminium by itself suitable for certain climates.

One of the things that the enameller has to do is to prepare the specifications, or help the architect to do so. A problem is waviness and flatness and there can be a great deal of argument about whether something is flat or not. At Princeton University, in a research on stainless steel, the problem of flatness was investigated in an elaborate way and a method of measurement produced ; as a result of this, based on the slope of the curve of the distortion, it was possible to judge whether or not a given distortion would be objectionable. This is an excellent method based on a P.E.I. test developed about twenty years ago and which had never been used.

The question of matt or semi-matt finish also needs consideration particularly as the author has seen a semi-matt finish which had a gloss, and vice versa. In addition there is a need for standardization of colours, and that is something on which the P.E.D.C. and the I.V.E. should work together. Other questions that can be asked are what is a good adhesive and what is a good sealer or mastic ? How can insulation be checked? There are tests available from the A.S.T.M. and the B.S.I. which are applicable in certain cases, but they are no good for this, and it is necessary to have a method of test so that the architect can put in the specification something which will guarantee that when he buys from the enameller he knows what he is going to receive.

These are some of the obvious points. The author has tried to show that the enamelling industry has some problems, and that they are big problems, not only for the P.E.D.C. but for the I.V.E. also. It should not be overlooked however that assistance from the adhesive suppliers, the

sealing suppliers and others, will assist in solving the problems associated with curtain walling, in which all enamellers are interested.

EXPERIENCE IN THE U.K.

by T. J. MacArthur

THE technique of enamelling steel panels for architectural purposes follows broadly standard processing methods, with certain specific changes introduced to obtain the particular qualities which have been outlined already by Mr. Mackasek. Some of these qualities which do affect processing methods can be listed. First, a high standard of colour matching and evenness of colour on individual panels is essential to cover large, flat areas such as building elevations. Second, the degree of flatness in the finished panel must be consistent with the aesthetic requirements ; in other words, if a flat surface effect is desired, it must be in appearance literally flat and not just miss the mark. Third, there is the question of textures of enamel finish and particularly the degree of gloss used. Finishes are introduced in certain cases to assist in producing the effect of solidity and flatness. In general, experience shows that flat finishes are preferred by architects and heavy stipples meet with heavy sales resistance.

Bearing these three major points in mind, it will be appreciated that, although the enamelling process follows the general lines of standard procedure, or in other words the procedure for enamelling sheet steel, certain changes are adopted to conform to these particular quality requirements. The question of colour stability and evenness throughout individual panels is extremely important, and, coupled with the aim of flatness of appearance, frits have been formulated particularly for architectural purposes. These enable the enameller to apply coatings of variable gloss and surface texture.

It is essential that such enamel finishes should be acid-resisting, at least to the standard 10 per cent citric acid test and particularly to B.S.1344. This is confirmed by the recent report on 15 years weathering from the National Bureau of Standards, in which weathering tests were carried out in coastal and industrial areas etc. across the United States. That is a most valuable piece of information.

It is not possible accurately to match every colour in fully acid-resisting enamels, but the architect is impressed by the tremendous range of colour offered to him. Often the architect will require what may be called an exotic colour. It is possible to match almost any shade or colour in enamels, but not always in acid-resisting enamels, and in that case the architect should be informed that he has to make a choice between less acid resistance to obtain certain colours and better acid resistance. The work should be carried out only with the architect's agreement.

Enamellers, generally speaking, require four frits for this purpose. The first is a fully opaque frit, which when fired alone at 800° C. gives a completely matt finish. The second is a semi-clear frit, with full matching properties, the third a semi-clear frit of the conventional glossy acid-resisting type and the fourth is a very clear, almost transparent frit of the fully-acid-resisting type. These frits can be mixed during melting, and, by varying the proportions used, the gloss and the opacity can be controlled. That is an elementary point to enamellers. There is a variable opacity to meet the demand for certain colours. As an example, light shades of colour with very matt surfaces may be met by having a mixture of 60 per cent fully matt frit and 40 per cent of the semi-opaque, acid-resisting frit. A brilliant and deep colour with a matt surface means 60 per cent clear matt frit, so called, and 40 per cent transparent glossy frit. The variations in gloss which can be obtained are infinite. Heavy textures can be obtained by stippling, but architects generally do not like stippling.

To achieve the property of flatness is of the highest importance, but it is one thing to talk about it and another to go to the trouble in handling to produce it. It is necessary to hang the panels during firing to achieve perfect flatness. This will avoid at least localized points of distortion, normally caused by firing fine glass quartz. This will produce a panel without local distortion or waviness, but it may still have a slight " oilcan " effect which can be eliminated only by pressure bonding the panel to a rigid backing material. Since most architectural panels need to include insulating properties, insulating material can be used which has the necessary property of rigidity. Some manufacturers both here and in the U.S.A. produce a mechanically-assembled panel with an enamelled steel face and insulating material fixed at the back. It would appear that the degree of flatness achieved by this method of assembly does not compare with that obtained when the panel face is bonded by adhesive under high pressure to a rigid backing material.

The importance of flatness in appearance cannot be over-emphasized. It is so important that the material as a constructional material can fall down on that one count. If it becomes generally accepted by architects and construction companies that enamel must be wavy and unpleasant in appearance its use will die out. No local distortion of waves or bulges must show, because they become emphasized once the panels are fixed in the higher

elevations of the building. If the enamelling industry intends to develop this architectural market, the manufacturers will need to ensure that these quality standards are met and must use the type of plant necessary to produce a good job.

Discussion

THE CHAIRMAN said that Mr. Mackasek had dealt not so much with curtain walling as with technical development, about which the members of the I.V.E. knew a good deal, because when they wanted to do something their directors would say " Has somebody else done it ? Can you take me to see it ? " He himself was a consultant, and his firm employed architects. The field of the architect was extremely wide, and the correct plan would seem to be to employ an architect and educate him in this application of vitreous enamelling, which was a matter for the V.E.D.C. rather than the I.V.E., and then let him go with the technicians in vitreous enamelling to show other architects what could be done.

His firm were often responsible for building foundries in particular, and attached to a foundry there was always, nowadays at any rate, a canteen, which caused far more trouble than producing a hundred tons of steel castings a week. The association of the framework with what was required within the building was most important. He believed that the waviness of the steel sheet was entirely due to thinness, and he thought that the holloware industry, in reducing the thickness of their materials, had done great harm to vitreous enamelling, other than to cast iron.

DR. W. H. F. TICKLE, also referring to waviness, said he had seen a few buildings in which vitreous enamel was used, and he thought that to some extent the importance of waviness had been exaggerated by the openers of the discussion. He felt that every building material had its own characteristics. When Antonio first tried to sell marble in Florence, the architects said that it could not be used because there was a pattern running right through it. But it was used and this pattern became symbolic of marble. In the same way, this effect with the use of vitreous enamel in buildings he found quite pleasant. To attempt the impossible was no doubt worthy of everyone's endeavour, but he thought that it put the picture rather out of perspective. A certain amount of waviness was not altogether bad.

MR. T. J. MCARTHUR stated emphatically that Dr. Tickle's views if carried out in practice could do more harm to the architectural market than anything else. Deliberately and artifically to corrugate the panel was extremely good, because it achieved what it set out to do ; but a panel which looked as if it was meant to be flat but had obviously, in the eyes of technically trained men, such as architects and builders, just missed being so was not a suitable material. Patterned surfaces looked good but required fairly costly tooling. The fact had to be faced that it was possible to make a flat panel. It was being done every day, and, once an architect had seen a flat panel, it would never be possible to sell him a wavy one.

MR. E. MACKASEK liked Dr. Tickle's idea and wished it were possible to agree with him. Dr. Tickle's argument had been advanced many times, but to attempt to change the architect's idea of beauty was impossible. The facts had to be faced and waviness reduced until it was unobjectionable. The whole use of metal for walls was involved. Those who had seen the stainless-steel buildings in Pittsburgh would know that the stainless-steel producers had an even more difficult job than the vitreous enamellers ; many of the panels used in those buildings would have been rejected by the enameller as soon as he saw them. It was essential to eliminate waviness and to devise a test for it.

DR. B. K. NIKLEWSKI said that in Europe, and particularly in Sweden and Denmark, there were firms which specialized in putting what was just a skin over old masonry, to make an old building look new. That was also done to a considerable extent in America. How was the volume of the architectural work divided up between putting a skin on old buildings and providing new curtain walls ?

MR. MACKASEK replied that that was a very interesting point, because emphasis was continually placed on the curtain wall, as a glamorous feature, and the architect liked to use vitreous enamel for that purpose ; but today, in spite of the tremendous development in curtain walls, the use of vitreous enamelling as a cladding or veneer exceeded its use for curtain walling, and would continue to be big business not only for old buildings but for small structures, for which the use of cladding often avoided many difficult problems. He had not had time in his introduction to bring that out, but they should not be led, by the glamour of this new and spectacular field of curtain walling, to neglect the opportunities in the cladding field, which was a fine field to cultivate and offered good opportunities not only for cladding but for the components which could be worked in with it.

MR. MCARTHUR added that he had been associated with a shop-front veneering or recladding job in 1939. It was still in existence, and the owner of the shop had not had to spend a penny on maintenance, which was important.

MR. PERKS pointed out that waviness could result from too many coats on one side and none on the other. He hoped that enamellers would not take

the view that the ground coat would be sufficient on the back, because it would not be ; unless as much was put on the back as on the front there would be trouble.

Reference had been made to vitreous-enamelled signs, put up fifty years ago. The specification for these, as he knew to his cost, had been to glaze them highly after finishing, and that had been the reason for their success in any atmosphere and under all conditions.

MR. MCARTHUR referred to the job, mentioned earlier, done in 1939 in an industrial area, a mill town. That had been done in semi-acid-resisting enamel of pre-war type, and it was still quite good. It was in light ivory and very dark grey, which was generally regarded as a bad colour for weathering.

He was pleased that Mr. Perks had raised the question of backing enamel coatings. That was essential with all laminates, and an enamelled steel sheet was a laminate in the sense of the coating of both sides of the steel with glass. It was not sufficient to leave the back in the ground coat only for two reasons, one of which, as mentioned, was to compensate on the back for the coating on the face, in order to prevent waviness and distortion. The other reason had been brought out in a National Bureau of Standards report, which stated that where specimens had been weather-tested, after 15 years with ground coat only on the back, the handling marks in that ground coat were down to the bare iron and the panels corroded through to the face in an average of five years. The backing coat, therefore, served two purposes : it stopped any chance of corrosion from the back of the panel, and it helped to achieve flatness.

MR. SYMONDS said he would like to hear discussion on whether to have thicker or thinner steel for the panels, and also whether the panel was to be flanged with corners welded up or merely a thin flat piece of steel. Thin steel could be pressed to a rigid infilling more easily if it were distorted. If thick steel was used it was very hard to press it down and join it to an infilling. Whether to use a very thin sheet of steel with no flanges and laminate it to something, or to use a heavy, solid panel — and even with 16 gauge it was easy to get distortion — he did not know. Did the enamel contribute to thermal insulation, as compared with other things ? Had the enamel industry anything to sell in that respect ?

A MEMBER raised the question of the time taken to replace a damaged curtain wall or cladding panel. Reference had been made to glass panels being damaged by small boys throwing stones at them. Was it as easy to replace the enamelled panels as the glass ones ?

MR. FIFE-SMITH asked why reference was being made only to steel panels and not to cast iron. He was sure that something equally good could be done in cast iron.

MR. NICHOLLS said that from the slides shown of American buildings most of the panels had a high gloss finish. Was that due to atmospheric conditions or to appearance ?

MR. PHIPPS asked where the responsibility of the enameller ended. Was it when he had done the work and packed it and sent it to the site for erection, or did he have to keep a fatherly eye on it afterwards ? The standard of the British building worker today was not very high, and he doubted their ability to erect the panels without damage.

THE CHAIRMAN, replying to the last question, suggested that the responsibility of the enameller ended when he received his cheque, and that might take a long time.

MR. MCARTHUR, dealing with Mr. Symonds's point about the use of thin or thick steel, said that thanks to friendly relations with the American manufacturers information had been obtained on the average gauge of steel used in the United States. It would appear that on the larger panels — and the panels were, in response to demand, becoming larger and larger as time went on — 16-gauge steel seemed to be about the average. In the laminated type of panel 20 gauge was used for smaller sizes, but 20 gauge distorted much more easily over large areas. He had in mind panels of 20-30 sq. ft. It was possible to keep an unflanged or flat sheet in 16-gauge steel absolutely flat. He had a photograph of a building in which panels 5 ft. x 3½ ft. had been used as flat sheets only in a glazing system, or in other words in a window-frame system, purely for decorative purposes, and they were really flat, with no backing or bonding to other materials.

With regard to the use of cast iron, if a panel could be made in cast iron of the order of 8 ft. x 4 ft. and which would enamel well, he would use it.

MR. MACKASEK said that in the United States the advice was being given to get away from high gloss. On the West Coast semi-matt had been used almost exclusively for the last ten years for all the structures there. The East Coast had used high gloss, but was now going in for a semi-matt finish. A fully-matt finish was not used for several reasons ; it caught the dirt, and it was not possible to check the acid resistance of a full matt finish. Semi-matt was the finish principally used and specified by architects.

The question raised by Mr. Symonds was one which had been discussed a great deal in America, and there was a difference of opinion on whether, in laminated construction, to use heavy or light gauge steel. One of the leading enamelling companies in the United States would not laminate anything less than 16 gauge, while another would

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Enamelling of ALUMINIUM

by A. BIDDULPH

A paper presented at the Annual Conference of the Institute of Vitreous Enamellers, Chester, October 3 and 4, 1957

THE development of enamelling is a story of the growth of an art into an industry.

From the ancient Pharaohs and throughout the old World, goldsmiths and silversmiths used enamel to decorate their wares, which were mostly sacred objects. Two hundred years ago enamel was also used on base metals such as the copper snuff boxes and trinkets of Bilston and Battersea.

Early in the 19th Century enamels were applied to cast iron for a utilitarian purpose as a glossy lining on cooking utensils. With the invention of steel-making by Bessemer, Siemens and others there was soon a demand for enamel coatings on sheet steel as well as on puddled iron sheet, resulting in the establishment of the sheet-iron holloware industry. Thus what was first used, and is still used, as an adornment for precious metals became a utility surface for general use, especially in the kitchen.

By the turn of the century industrial enamelling included a wide range of domestic and commercial equipment in sheet steel as well as cast iron. As the advantages of the lifetime finish and wide colour range available with enamel became more generally appreciated the scope for utilization of an enamel surface continued to extend.

More recently the tremendous increase in the production of aluminium, called for to meet the wartime demands of the services, became available for peacetime industry. It was utilized for old and for new purposes, and in some cases as an alternative to steel when that metal was only obtainable against " M " forms. Some of these purposes required a permanent decorative finish such as enamel provides, and some enamels in a limited range of colours were evolved but their use was also limited, partially by the narrow range of colours available and partly by the difficulties of application and by price. For dress jewellry and trinkets, aluminium had been used and enamels were available for its decoration, but these were in a price range which placed them outside the field of use for domestic equipment.

It may be asked why apply enamel to aluminium ? There are several reasons for doing so. First of all for decoration, for providing a colour other than the natural colour of aluminium, pleasant though this may be, and second, for the prevention of corrosion, particularly for outdoor uses of aluminium as a building material

It is often claimed that aluminium does not rust, which is the case as rusting is specifically a description of an occurrence in relation to iron. Aluminium, like most metals, does oxidize in air and under some conditions of weathering will oxidize severely. In resisting such conditions enamelling has many advantages.

In elementary terms enamelling involves the application of a frit or glass suitably compounded, ground and suspended, to a suitably cleaned metal surface, followed by heating of the metal to cause the particles of frit to flow together and to produce a continuous glossy surface upon the metal. There are many properties required of such an enamel, in terms of colour, gloss, smoothness, hiding power, resistance to acids and alkalis, to thermal shock, to heat, to mechanical damage. All the foregoing are qualities present to a major or minor degree depending on the extent to which they are necessary for the particular purpose of the enamel. There are, however, two functions of an enamel which must be controlled rigidly ; these are not normally mentioned, however, because they are so self-evident that an enamel that does not satisfy the conditions is not useable. The enamel must have a softening temperature below that of the metal to which it is to be applied, and should also have an expansion that is compatible with the metal.

While enamelling of aluminium satisfies the elementary principles mentioned there are many ways in which the detail of enamelling differs from enamelling of sheet steel, and it is these differences which it is intended to discuss, assuming a previous general knowledge of sheet-iron enamelling.

In the enamelling of sheet steel enamels are used with a softening point or rather fusing temperature of between 750 and 900°C., on a metal which has a melting point in the region of 1500°C., although it is becoming soft enough to become distorted in firing at 900° C. The expansion of the enamels is somewhat lower than that of the steel. It is customarily expressed as a coefficient of cubicle expansion per degree centigrade x 10^{-7}, the figure for steel being around 400 and for enamel usually between 290 and 330, as measured in the

range of 20° to 300°C. In the case of aluminium the metal, as commercially used, and sometimes containing alloying elements, has melting points from 560°C. to 660°C., and expansion of the order of 650 to 720. Thus to apply an enamel coating successfully to aluminium and its alloys an enamel is required with a fusing temperature below 560°C. and an expansion much higher than any enamels used upon iron. In making such an enamel it is necessary to look beyond the orthodox range of frit materials, and also outside the usual price bracket.

Metal Preparation

A clean metal surface, in a state suitable for applying the enamel is just as necessary as with steel, and with similar variations to meet differences of metal as received.

Handling of aluminium requires care to avoid scratching of sheets by sharp edges or by dust particles that may get between sheets. Scratches produce ridges of metal that may protrude through the thin enamel coat causing blemishes, or larger particles may be embedded in the surface of the soft metal.

Cleaning of sheet metal includes immersion in several solutions, which may vary according to the particle alloy of aluminium concerned. There are proprietary cleaners available, each with their special purposes, and claims.

First the metal is degreased, usually by solvent degreaser, but this may require preliminary wiping if the ware has been lubricated for press operations.

Extrusions often require the removal of gross grease such as tallow, before vapour degreasing.

A general-purpose cleaner bath is made up as follows :—

Sulphuric Acid	6.0 per cent.
Detergent	0.5 per cent.
Water	93.5 per cent.
Temperature	20 to 25°C.
Time	15 to 20 minutes.

Several household detergents are suitable as additions to this bath. After rinsing the ware in water it is then placed in a chromate bath made up from :—

Chromic Sulphate	0.241
Potassium Dichromate	17.7
Sodium Hydroxide	9.5
Water	96
Temperature	49°C.
Immersion time	2 to 5 minutes.

This is followed by rinsing in clean running water, and brushing to remove any loose deposit from the ware, which is then placed in warm air to dry off.

Several of the low alloys of aluminium can be coated effectively without immersion in the chromate bath; S1C, NS3, NS4 are in this category.

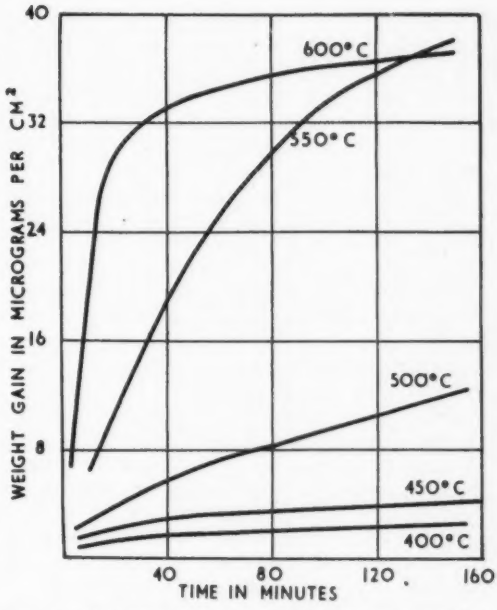


Fig. 1.—Oxidation tests of metallographically polished specimens degassed at 600°C(1).

The ware is next heated to a temperature within 20° of enamel fusing temperature, to promote the formation of a thin oxide film. The purpose of this film is to provide a passive oxide layer between the metal and the enamel and thus avoid excessive reaction between the alkaline slip and the metal base during the firing cycle. Omission of the pre-firing is sometimes possible under favourable conditions ; otherwise such omission will result in blisters.

It is likely that the oxide film is a factor in promoting adherence of the enamel, but sufficient oxide to achieve adherence may be produced during the enamel firing cycle. In cases where metal has been enamelled without preheating, the adhesion has been good even though blistering may have been severe. It is not often that poor adhesion is encountered, although there are other difficulties to ensure interest.

At the usual firing temperature of 540° to 560°C. an oxide film is formed much more quickly than at 500°C. and below. Tests made to determine oxide formation by increase in weight were found to give inconsistent data, and further work showed that release of gases during heating could be a cause of inconsistency. Some work performed by Smeltzer[1], who first degassed aluminium samples before oxidation, indicates the comparative rates of oxidation at different temperatures, as shown in Fig. 1.

Castings

Similar cleaning procedure may be used for castings, with modification of immersion times to secure thorough cleaning of the casting skin.

Blasting with a non-metallic abrasive followed by pre-firing has shown fairly good results, with some pieces cast in sand.

Some difficulty has been experienced with pressure die castings. After cleaning and during preheating several instances have occurred where blisters have formed over the surface of the casting, blisters similar to laminations in sheet material. These may arise from expansion of gases trapped within the metal at the time of casting, and may be aggravated by the cleaning operation. Much work on this subject remains to be done.

Cleaning is followed by a heating cycle in which the metal is placed in a furnace and brought up to temperature near to or equalling the enamel fusing temperature. In certain instances it is possible to omit the preheating operation. It is sometimes found that metal that has been through the chromate bath will have a loosely adhering film after the preheating operation and this is removed by brushing over. The metal is then ready for the application of the enamel.

Milling

Enamels for aluminium have been developed which have low working temperatures and in some cases this has been achieved by use of lead oxide as a substantial proportion with the enamel batch. Most aluminium frits have a higher specific gravity than the usual frits for sheet steel, and mill charges carry greater weights. A mill with a normal capacity of 50 lb. sheet-iron frit will take 70 to 80 lb. of aluminium enamel frit.

Aluminium enamels generally are ground to a smaller particle size than steel enamels, partly to secure the most rapid softening of the particles when fired and partly to help suspension and also to aid in the smoothness of the thin coatings applied. Routine checks are made with a 325-mesh sieve and a typical specification is 0.1 gm. residue on a 325-mesh from a 50 c.c. sample. In practice a sample may be a multiple of 50 c.c. to secure a residue big enough to be determined. The rapid test method of measuring the residue by volume would not be applicable to such small residue, which should always be dried and weighed.

Sub-sieve fineness tests by the hydrometer method of several millings of enamel are shown in Fig. 2.

Mill addition materials have been evolved to suit the particular conditions of enamel and metal. The common suspending material, ball clay at about 5 per cent plus an electrolyte such as sodium

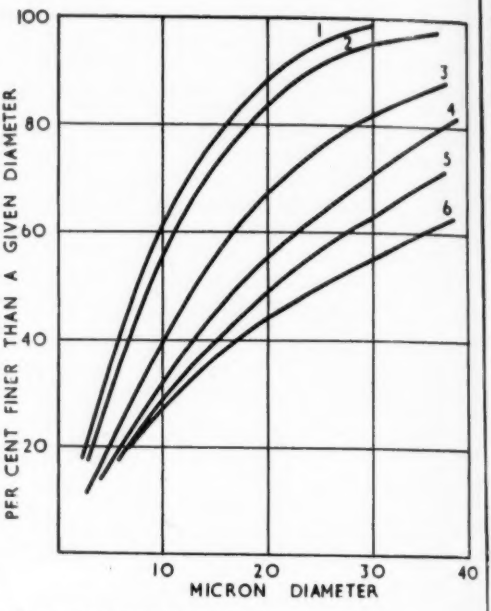


Fig. 2.—Sub-sieve fineness tests.

1. *AL-4 Frit*—0.022 *gm. residue on* 300 *B.S. sieve from* 50 *c.c. sample—Suitably ground.*
2. *AL-4 Frit.*—0.06 *gm./300/50.—Suitably ground.*
3. *AL-4 Frit.*—1.14 *gm./300/50—Coarse ground.*
4. *AL-4 Frit.*—8.6 *gm./300/50* and 2.28 *gm./200/50—Very coarse.*
5. *Titanium White for Steel*—1.4 *gm./200/50—Typical grinding.*
6. *Ground Coat for Steel*—5.3 *gm./200/50—Rather finer than normal Ground Coat.*

nitrite or sodium aluminate could be used to give suspension, but clay is a refractory material and while this refractory addition to sheet-iron enamel produces a rise in firing temperature which is permissible, the increase in firing temperature of aluminium enamel is too great to be acceptable. Although the behaviour of frit particles in relation to the metal surface during heating requires the presence of materials tc control crawling and promote wetting of the surface these must be assimilated into the enamel without detriment to the final surface.

Mill addition materials are required not only to give suspension to the slip but also to give a bond to the frit particles when the slip is dried and during the initial firing operation. The mill addition should be such as to promote wetting of the metal surface by the enamel and to provide resistance to cracking of the dried slip due to thermal shock when the ware is placed in a hot

furnace. In any fusing operation exposed metal will tend to rise in temperature quicker than the biscuit enamel because of the higher conductivity of the metal, and also because it is a continuous body. In the case of aluminium which has a very good conductivity this phenomenom is very noticeable and would tend to exaggerate cracking of the biscuit. Thus the materials added at the mill must provide suspension, binding and wetting, preferably without raising the firing temperature of the slip.

Considerable experimentation has been necessary to secure a workable mill addition, and one that has been popular is 3 per cent boric acid and 3 per cent metasilicate. Later it has been found that a reduction of these materials to 2½ per cent of each plus half of one per cent bentonite has shown improvement of suspension in some conditions, and this is a much more satisfactory addition for the slip which is to be used for spraying on flat-ware. In the case of intricate shapes with acute changes of plane and of varying thickness, there have been tendencies to tearing at such irregularities. At the present state of development the most satisfactory mill addition has been found to be boric oxide, 3½ per cent., sodium hydroxide 2½ per cent and a proprietory suspender, Silka, 6 per cent.

The usual standards of cleanliness in enamel preparation are necessary with aluminium enamel, but doubly so if aluminium enamels are prepared in the same place as steel enamels. Storage of aluminium enamels is preferably effected in enamelled bins ; galvanised and tinned containers may be used but may cause contamination. Enamel slips when stored will tend to settle just as steel enamel will, but possibly to a greater extent. Also they have tendency to flocculate in lumps of the order of 1/8 in. and it is desirable that enamel should be sieved through 80 mesh shortly before it is used.

Application

Unlike the orthodox enamelling of steel, aluminium enamel finished coat can be applied direct to the prepared metal. Ground coats are not necessary. Application may be by spraying or dipping or flow coating, but spraying is preferable. A finely ground slip does not drain as well as a typical sheet-iron ground coat. For spraying, a fine fluid tip and air cap is used, considerably smaller than the usual enamel spray gun and similar to a typical paint spray. Coatings are of the order of 12 gm. to 18 gm. wet weight per square foot and it is necessary that a wet spray shall be maintained. With suitable production quantities automatic spraying can be utilized.

Slip viscosity is lower than steel ground coat.

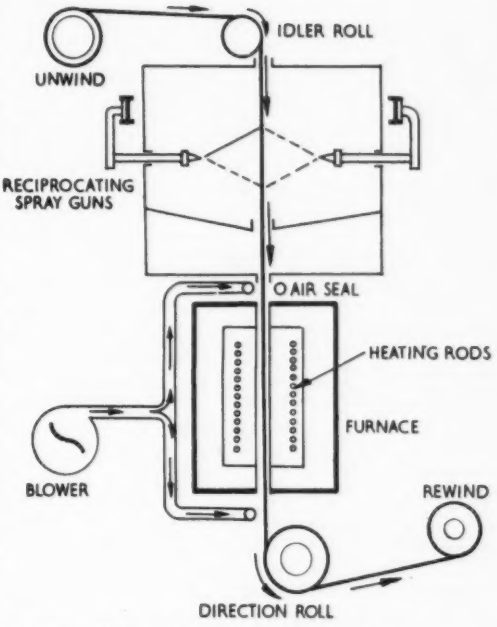


Fig. 3.—Outline view of foil-enamelling plant.

Specific gravity is between 1.95 and 2.05. Spray application is sometimes made on the face side only but it is more common to apply the enamel on the back of the plate as well as the face to avoid warping. Although aluminium frits have considerably higher expansion than steel frits they are still well below the expansion of aluminium and tend to pull the surface unless they are applied on both sides. In production, spray booth reclaim could be used for the back side of plates.

One encouraging factor in aluminium enamelling as compared with steel enamelling is that misprays, bare patches, etc., can more readily be made good. The aluminium sheet is prefired to raise a passive oxide film and if there are any bare parts the extra oxidation during the firing of the aluminium is quite small and the exposed surface is still good as a base for enamelling, thus any bare parts can easily be coated, as can also any pinholes resulting from tears that have not healed up.

Drying

In many instances it is not necessary to dry off the water from the slip before the ware is fired, although production conditions may make it desirable that drying is carried out. If, however, production quantities justify having automatic spraying and continuous furnace, the ware can go

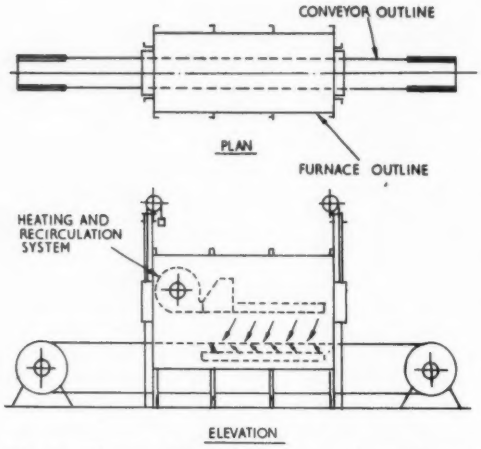


Fig. 4.—Diagram of lay-down type continuous furnace.

wet into the furnace so long as there is sufficient ventilation to get rid of the water vapour.

Often, it is desirable that certain parts shall be kept clear of enamel, a requirement which is met in the case of steel enamelling by brushing off the cover coat. Aluminium enamels, however, do not respond freely to the brushing technique. The dried slip is hard and tenacious and a brush that would remove the biscuit enamel would probably also score the metal surface. Enamel could be kept off the metal by wiping off while wet or by masking off with tape or with a latex solution such as " Copydex."

An interesting field for use of enamel on aluminium is in the production of enamelled foil. While it would be possible to apply enamel to a small piece of foil, *e.g.* 2 ft. x 1 ft. there are considerable difficulties in handling. The material is light and being less than 0.01 in. thick is not strong, therefore it requires to be handled very delicately. When sprayed, the air from the spray gun tends to blow it about like leaves in autumn, and in the furnace convection currents could waft it about like a sheet of paper. The usual way of enamelling aluminium foil is to use the metal in a coil, that is a coil of foil. The half mile length of foil is wound upon a 2 ft. diameter drum, from which it passes from a feed roller vertically down through the spray booth where the enamel may be applied to both sides of the foil. Continuing downward it passes into a furnace electrically heated. Emerging at the bottom of the furnace it cools off rapidly, passes under a roller to the rewinding drum from which it is cut off in lengths as required. The main commercial use of such foil is by bonding the cut lengths to hardboard on one or both sides for use as partitions and in some cases for exterior walls.

An outline view of a foil enamelling plant is shown in Fig. 3.

Fusing

Fusing temperatures at present in use for aluminium are of the order of 530 to 550°C., and it is highly desirable that the selected temperature shall be maintained plus or minus 5°C. Most furnaces that are built for 850°C. would not be capable of providing such a controlled temperature at 550°C. With electrically heated furnaces it may be possible to adapt the furnace by means of baffles to secure a more even heat. This has been done in the author's own development work where baffles have been designed so that there is not only a baffle between the heat source and the ware but air convection currents are induced within the furnace.

If, however, a furnace is to be built for enamelling, recirculation of air is a convenient way of securing even heat distribution, and several continuous furnaces have been built where this principle has been applied.

A diagrammatic view of a lay-down continuous furnace is shown in Fig. 4.

In the actual firing of the ware adequate support is necessary, even more so than with steel. Flat ware should be fired on points at about 2½in. centres instead of the usual 4-in. centres as used for steel. Owing to the lower temperature, however, perrits can be made of very light material. Stainless-steel bars of 1 in. x 3/32 in. sheet with points made from 1/8 in. wire about 3 in. long will be quite strong enough for the purpose, and will give long life with minimum corrosion. That is for flat ware. In the case of holloware, supports should be as in the best practice as used for steel holloware. In the case of other shapes adequate jigging is required.

To the question of jigging must be added that of metal composition. The melting points of aluminium alloys vary between 550 and 660°C., although the materials most likely to be encountered such as 99 per cent. aluminium, NS3, NS4 and H.9, have a high enough melting point to be safely fired at 560°C. Some other alloys, however, have much lower melting points and can only be fired by taking every precaution in jigging and by firing at a rather lower temperature for a longer time.

In conclusion, the author wishes to thank the directors of Ferro Enamels Ltd. for permission to present this paper, and his colleagues for much help in the practical work that forms the basis of these observations.

Reference

(1) Smeltzer, W. W. " Oxidation of Aluminium in the Temperature Range 400 to 600°C.," *J. Electrochem Soc.*, **103** (4), 1956, April.

Discussion

MR. J. C. BAILEY (Aluminium Development Associstion) said that the paper took his mind back to the Conference held by the Institute at Torquay in 1950, at which a paper on the vitreous enamelling of aluminium alloys had been discussed. He believed that that was the first occasion on which the subject had been discuused at a conference. It seemed that in 1950 there had been many formidable techinal problems in vitreous enamelling to be solved : the composition of the frit had been uncertain and it had not been known which of the various possibilities to choose. With regard to possible applications, no one at that time had thought of any use to which the product could be put, once it had been successfully made.

Today the outlook was very different, and Mr. Biddulph had shown the progress which had been made in the last seven years. As had been said earlier, curtain walling had come in, and with it a very extended use of aluminium, at least for the vertical parts of the curtain wall, if not for the panels. That had given a great impetus to development work on the vitreous enamelling of aluminium, and was possibly one of its major uses in the foreseeable future.

The aluminium industry had tried to assess the situation but it was not easy to do this. The industry provided aluminium and contended that it was satisfactory without any surface coating at all, so where did vitreous enamelling fit in in relation to that, and in relation to other finishes which could be applied to aluminium, such as anodizing, which also gave colour ? It seemed to the aluminium industry that vitreous-enamelled aluminium must be thought of as a product rather than as a process, and that its characteristics as such had to be studied. It was a mistake to compare it with vitreous-enamelled steel.

From the aluminium side, it was looked upon as another finish for aluminium and it was assessed accordingly. On that basis, what were its distinguishing features ? This was a new and different finish for the material, and therefore it would attract attention if only because it was new, which was quite sufficient in these days to bring any product into notice ; and also it provided the architect with another range of colours and textures. Second, it was very durable being a combination of glass and aluminium, both of them extremely durable products. It had yet to be shown how durable it was, but the oldest erection in vitreous-enamelled aluminium was nine years old and still going strong, so that some long-term information was being built up in that way.

Third, it had the quality of being able to withstand a good deal of deformation, an important feature with regard to its durability. He did not know what would happen when small boys threw stones at vitreous-enamelled aluminium, and there was not a great deal of guidance on that, but it seemed unlikely that severe corrosion would set in at the point of impact. This quality was also important in allowing the rectification of a vitreous-enamelled product which had lost shape in the furnace or for some other reason. All the formed sheets which were being regularly produced went through rubber rollers to straighten them out after rolling and provide the requisite finish for use on buildings.

The particular casting alloys which were suitable for vitreous enamelling were among the more ductile and would themselves withstand a good deal of deformation, so that it should be possible to rectify, and indeed do a little shaping on, a vitreous-enamelled casting if the right alloys were chosen. In addition, it would be noticed that, particularly in the case of the foil samples, the aluminium had a great deal of rigidity. Aluminium sometimes needed to have more rigidity than was normally available from the basic properties of the material, and perhaps the vitreous enamelling would help in that situation.

The vitreous enamelling of aluminium, moreover, was applicable, as the author had shown, to welded components, and there it had an advantage over anodizing, which, though applicable to some welded units, such as flash welds, was not readily applicable to argon-arc welds or gas welds. There was an important place for vitreous-enamelled aluminium because of that property.

Could the author say anything about the strength of the product at elevated temperatures, such as 100-150-200°C., which were temperatures at which aluminium alloys began to show signs of weakening ? That might be important for certain applications, including fire resistance of buildings and curtain walls.

An attempt had been made to speculate, though it was difficult to do so, on what the fields of use for this product were going to be. So far, building seemed to be the main one, and that undoubtedly would be a major field ; but, because of the property of resisting mechanical damage, and the possibility of rectification of the enamelled product, it might be found that nicely coloured products with the smooth finish characteristic of vitreous enamel might prove useful for a good many domestic appliances, such as vacuum cleaners, and perhaps even for furniture of new design. That might open up quite a field of use, but that remained to be seen. There would be special uses due to electrical resistance, non-magnetic properties and things of that sort which might come along in due course, although perhaps not to any very great extent.

All that, of course, depended on the price of the product. Mr. Biddulph had not mentioned that, but it would be helpful to everyone in thinking

about this untried product if he could give some indication of how it stood in relation to other finishes with which it was likely to be to some extent in competition, though not necessarily so.

MR. GRIFFITHS, speaking as a vitreous enameller and an anodizer of aluminium, said that vitreous enamel had the great attribute of being permanent in its colour, whereas anodizing was suspect, though anodizing was being applied to such parts as window frames and the anodizing associations stated that certain dyestuffs were permanent.

Mr. Biddulph referred to the oxide film. Could he give an indication of the desirable thickness and say whether it could be applied by anodic oxidation, which could be controlled in tenths of a thousandth of an inch, from 0.0001 to 0.001 in. ? Also, what would happen to enamel which had been fired for a short time at a higher temperature than that stated in the paper ? Mr. Griffiths asked this because he had fired it at a temperature indicated as 800°C. Next, could a dry enamel be applied over an adhesive coating such as gum arabic, to provide another means of coating ?

In the first part of the paper reference was made to the use of enamels in the time of the ancient Pharaohs. Mr. Griffiths had been told in his school days that the Pharaohs only set glass into settings and did not melt it under the surface of a metal. Andrews, in his book on enamels, claimed the origin to be American. Mr. Griffiths would claim the origin of enamels to be British, in the West Country. There was evidence in the British Museum of their use earlier than the third century.

MR. J. W. PEDDER said that so far as he could remember when the subject had been discussed at Torquay the question of oxide had not been raised at all. Perhaps there had been an improvement in the process, and that was now desirable. With regard to thickness, could Mr. Biddulph give any indication of the thickness used on ordinary sheets ? When for foils a thickness of 0.01 in. was given, was that the thickness of the foil and the enamel, or could Mr. Biddulph give the thickness of the foil and the enamel applied in each case where the thicknesses were given as 0.002, 0.005 and 0.01 in. ? Was it desirable to put a coating on both sides of a casting, and with a hollow casting should the coating be put on the inside as well as the outside ? Could the material be used for architectural purposes, and what were its acid resisting properties ? Had it been possible to get away from the use of lead, and was there a danger of contravening the Factories Acts by using an enamel which probably contained more than 0.5 per cent of lead ?

MR. BIDDULPH, in reply, said that Mr. Bailey's remarks had been in the main complementary to the paper. He could not give an answer on the question of the strength of the product, but there was no reason why an effort should not be made to find out how the strength was increased by the presence of the enamel coating. He thought that it would add to the strength of the material, particularly at temperatures high enough to reduce the aluminium strength but lower than the softening point of the enamel. On the question of the price of the product he did not know enough about production costs to be specific, but if one sent to the jobbing enameller a piece of steel to enamel and wanted it in whites it would cost about 2s. per sq. ft., and he thought the cost would be 3s. to 4s. if it was aluminium. The frit was expensive. With improved working conditions it might be possible to reduce the cost of some of the operations.

Replying to Mr. Griffiths, he said he had no information about the thickness of oxidation. He knew, however, that anodic coatings were not beneficial to enamel ; when given samples to be coated, if they had been anodized it was necessary to strip the anodizing off before they could be enamelled. Firing could be done for a short time at a high temperature. He had brought with him three plates, all with the same enamel but fired under different time and temperature conditions. They had used anything from 500 to 580°C. At 500°C. it took too long, and 580°C. was on the high side ; they had melted the aluminium before now in some of their experiments. The temperature, therefore, should be kept down to not more than 560°C., and in production conditions it was better to keep below the melting-point of the metal.

MR. PEDDER asked about the thickness of the enamel. On sheets of the order of 20, 18 and 16 gauge one coat would be about 0.003 in., and two coats about 0.006-0.007 in. On foil, the thickness in the case of the samples he had shown would be of the order of 0.002-0.003 in. He would not bother about doing the back side of a casting ; a casting was usually rigid and the pull of the enamel would not affect it. With regard to acid resistance, most of the enamels which he had used had an acid resistance of the order of A or A—. They had not absolutely perfect acid resistance and there would be a slight shadow with citric acid. Sulphuric acid, although it was no part of the test, had also been used, but they liked to go one better than the test. The acid resistance was of an order which would give good weathering. Some of the enamels were lead-bearing and some were leadless. Most of the colours could be obtained in lead-free enamel. The opacity was not such as to give a good type of white, but most colours could be obtained readily in leadless enamel.

Replying to Mr. S. E. A. Ryder, who asked if an organic suspender had been tried, Mr. Biddulph said that one organic suspender had been tried and the results had been disastrous, but another was to be tried in a few days time.

THERMOSTATIC VISCOSITY CONTROL

The Use of Cooling Equipment for Dip Tanks

By LEO WALTER

PAINT viscosity is a factor of great importance in the coating of metal parts and as viscosity is related to temperature thermostatic control is advisable in order to keep the viscosity constant. The use of special coolers for keeping paint at correct viscosity is described in the following text.

In the highly mechanized automotive industries parts are usually painted by either of two methods i.e. by the "dip" method where parts are dipped in a tank containing paint or by the "flow coat" method where parts pass between rows of carefully arranged spray nozzles and the paint is sprayed on. Except for the actual method of applying the paint, both systems are very much alike.

Prior to being painted, it is general practice to pass the automobile parts through metal cleaning processes, including a drying oven from which the parts emerge at an elevated temperature. As the parts are dipped in the paint bath and pass out of the bath on a conveyor line they are cooled from the temperature at which they enter the paint bath to the temperature of the bath itself. As more and more parts pass through the bath, the paint collects more and more heat — primarily from the oven-dried parts and to a lesser degree from the pumps used in the paint recirculating system.

In order to control the viscosity of the paint so that the film applied to the work will have the proper thickness and the correct characteristics, it is necessary to control the temperature of the paint. The most common problem is to cool the paint, although occasionally, for start-up operations, heat exchangers are used to heat the paint.

(*Continued in page* 426)

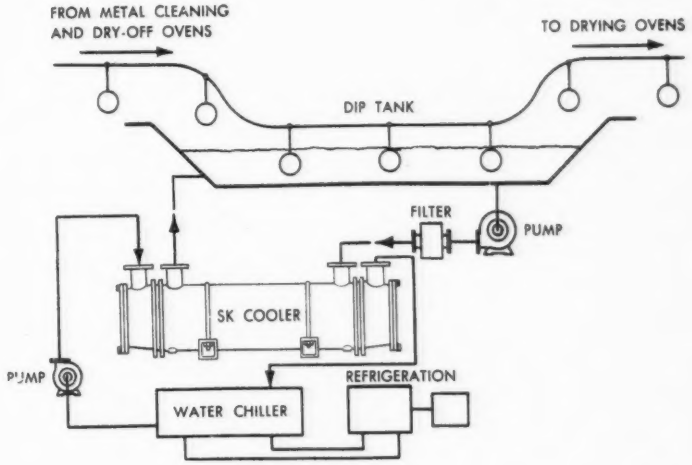


Fig. 1 (right) Simplified layout of dip system using cooler and water chiller.

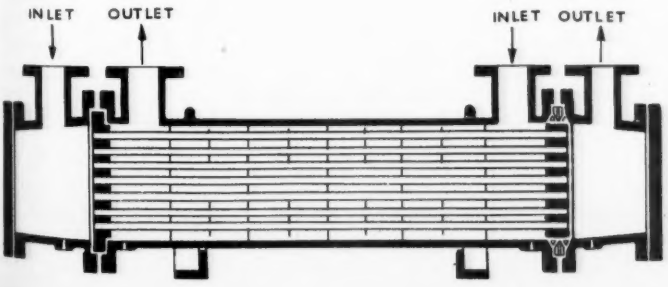


Fig. 2 (left). Sectional drawing of shell-and-tube type cooler as used for dip and flow-coat paint systems.

Thermostatic Viscosity Control

(*Continued from page* 425)

Fig. 1 shows a " dip " system typical of those used in the automotive industries. As in many such systems, this one uses a cooler to cool the paint which is recirculated through the system. The over-heated paint is pumped from the bottom of the dip tank through a filter into the cooler. Paint is cooled in the unit to the desired temperature and is discharged back into the tank.

Occasionally, plant service water is used as a cooling medium in the cooler. Usually, however, a conventional electric refrigeration unit with a water chiller, a centrifugal-type water circulating pump, and controls are used to recirculate chilled water to the cooler as shown in the diagram.

The size and design of the cooler used depends upon the requirements of the installations which vary greatly from one to another. It is necessary for example, to analyze the physical characteristics of the paint as these influence heat transfer and, from this analysis, to predict the coefficients. Then a cooler which will fit into the space available and which will be reasonable in cost for both the cooler and the water chilling system has to be selected.

Although every system differs, a typical cooler might circulate 100 gal. per min. of paint and 30 gal. per min. of cooling water. In a typical installation, the paint temperature is maintained at around 75 to 80°F. with cooling water entering the cooler at about 45°F. and leaving it at about 55°F. Heat exchangers of the shell and tube type are made in both single-pass and two-pass designs. Units of this type feature : a floating tube sheet closure using O-ring type seals which allow for contraction and expansion ; close fitting baffles spaced to provide maximum heat transfer ; removable tube bundle and cover plates for maintenance without breaking pipe connections ; and close-tolerance construction throughout (Fig. 2).

Not shown in the sketch is the automatic temperature control system which usually consists of two sections. Thermostatic control is used in the refrigeration plant which chills the cooling water to the desired temperature. The outlet temperature of the cooling water should be say 10°F. lower than the lowest paint temperature required.

Temperature control of the paint to be cooled can be performed in several ways. One method is to set the temperature regulator on the water chiller at the desirable cooling water temperature entering the cooler. The thermostat bulb or sensing element may be inserted into the pipe outlet for the paint leaving the cooler. Another method is to by-pass part of the chilled cooling water if less cooling action is required. A thermostatic by-pass regulating valve may be installed to this effect for diversion of return cooling water from the cooler.

Checking of the desirable viscosity of the paint in the dip tank will have to be made by a viscosimeter in order to supervise the effect of the paint cooling system and a visual and audible alarm should be provided to warn the plant operator in case of a defect. Supervision of the paint circulation pump and of the chilled water pump is also recommendable and regular cleaning of the paint filter is essential.

Abrasion Resistance Tests

(*Continued from page* 412)

purpose, in that they could not get reproducibility of the results between one apparatus and another and between one anodic film and another. They were not sure whether the troubles lay in the variations in the apparatus and methods of doing the test or in the anodic film itself. However, attempts were being made to streamline the whole thing and to use, perhaps, metal tubing and make the flow of abrasive under pressure much more uniform and controlled. In that way they hoped to bring the reproducibility to within acceptable limits.

It occurred to him that possibly such an apparatus might be of value on vitreous-enamel finishes. One could blow the powder on to remove a given thickness — just the surface layers, if that was what they were concerned with — and find the weight of abrasive required to do that, or go right through the enamel and find the specific abrasive resistance per unit of thickness.

This test, though still imperfect, had been put in the British standard for anodic oxidation finishes, of which a revised edition would be coming out soon ; but they did not regard it as a satisfactory test, even though it had got into a British standard.

MR. G. A. GREENWELL, referring to the little diamond testing instrument which Mr. Clarke had mentioned, pointed out that this had been designed mainly, if not entirely, for frit development work in the laboratory, and had not been as such thought of as a universal test. They had found it very useful, reliable and reproducible for the purpose for which it had been employed. At that time the I.V.E. had been trying to find a universal test, and Mr. Laithwaite had got them to make four or five of these little instruments up and send them to various members of the Institute for their evaluation. It had been very difficult to find five diamonds which gave the same result. One of the drawbacks had been that the sliding peg in the hole in the block could not be very loose or there would be rocking, while if it was too tight the friction inside the machine led to rather a higher result than would normally be obtained. Great care had been necessary in the manufacture of the sliding parts.

FINISHING

NEWS REVIEW

FOIL ROLLING COMPANY LOOKS AHEAD

New Mills at Silvertown Anticipate Industry's Future Needs

TOWARDS the end of last month, Sir Thomas Williamson, C.B.E., J.P., the secretary of the National Union of General and Municipal Workers and recently chairman of the T.U.C., performed the official opening ceremony of the new foil-rolling mills at the Silvertown, London, works of Venesta Ltd., Vintry House, Queen Street Place, E.C.4.

The ceremony marked an event in the history of the British foil-rolling industry for, along with increased productivity, the new mills are able to manufacture foil to meet the foreseeable standards of quality that might be called for in future years.

The demand for top-quality aluminium foil has grown tremendously in recent years, and is used today in electrical applications and the heat insulation of buildings as well as for such mundane purposes as milk-bottle tops and cigarette wraps.

Of the aluminium foil that is exported from Britain, more than one third comes from the works at Silvertown, and the existing annual output of the 300,000-sq. ft. factory is 6,500 tons per annum.

The weight of each of the four new two-high aluminium foil-rolling mills, able to roll up to a width of 30 in., is 60 tons. They have a combined output of 3,500 lb. of foil per hour, or 500 to 800 ft. per min. W. H. A. Robertson and Co. Ltd., of Bedford are the suppliers, and special features include a coil loading and unloading system, radio-active isotope thickness gauges, and a central rolling oil installation. The a.c. electric driving motors and switchgear were supplied by Laurence Scott and Electromotors Ltd., Norwich.

Coatings

To make it suitable for specific purposes such as heat sealing or for printing upon, the foil is treated with a coating which varies according to requirements. The coatings are made from base materials such as nitro-cellulose and vinyl or other synthetic resins, all of which usually have to be plasticized.

The foil is fed through machines where it picks up a flood application of coating from a roller revolving in a bath of the fluid. The weight of the coating is governed mainly by its viscosity, composition, speed, and the pressure of the rollers. Residual solvent is evaporated by two steam-heated drying drums. The vapour is passed through an active carbon recovery plant where after purification by distillation it is made fit for re-use.

Printing

Foil can be printed at Silvertown in up to four colours by the aniline process, and, at the firm's other factories, by the gravure process.

In the aniline process rubber printing cylinders bearing the design are used, and a heating drum at about 130° C. is employed to dry the foil after printing.

Laminating

For many purposes, such as packing cigarettes or butter, foil backed by another material such as paper or parchment is used, to confer on the foil properties of rigidity and strength it does not normally possess.

Known as laminates, they can be prepared by using water-based gums or emulsions, solvent-based adhesives, or molten adhesives. The gum is applied to the paper or foil which are then brought together and passed either over drying rollers or through a drying tunnel.

Molten adhesives include paraffin-wax, micro-crystalline wax, and bitumen. These are melted and applied to foil or paper, the webs being pressed together while the adhesive is still molten. Electrically-heated rollers ensure that the adhesive remains in a molten state.

Before the foil is re-reeled at the output side of the machine it must pass over cooling rolls or drums through which a continuous stream of refrigerated water is circulated. This eliminates any tendency towards de-lamination, and where the foil has been impregnated with wax, the surface is hardened.

The firm also manufactures foil in other metals including tin.

Left—Sir Thomas Williamson starts the rolling mill at Silvertown.

COMPANY REORGANIZES

CONTROL of British MonoRail Ltd. has been acquired by a group of industrialists and financiers headed by Mr. James Dallas, who have purchased the entire British shareholding — approximately 80 per cent of the issued capital.

Originally formed in 1952, the company will continue to operate from Wren Works, Chadderton, Lancs., as manufacturers of automatic transfer and overhead handling equipment. Their consultancy activities, which include the planning, supply and erection of complete mechanical-handling installations, will also be developed.

When the company was first formed, 20 per cent. of the shares were given to the American MonoRail Co. in return for full co-operation, including drawings, patents, goodwill and staff training facilities. This arrangement will continue under the new control, so that the British company will be able to use the "know how" of the American firm.

Mr. James Dallas has been appointed chairman and managing director of British MonoRail Ltd. He was for 12 years senior consultant with Production Engineering Ltd., and formerly with Wm. Denny and Bros. Ltd. and Ferranti Ltd.

Boron Chemistry Research Expands

New Laboratories Opened at Chessington

A newly-established research centre at Chessington, in Surrey, was put on view recently by Borax Consolidated Ltd., Borax House, Carlisle Place, London, S.W.1.

Still not complete, enough laboratories have been equipped to enable the present staff of 25 chemists, under Dr. Daniel Clapp, to start work on a new research programme. This is an ambitious one, encouraged by the quickening of general interest in boron chemistry.

One section of the centre's staff is working on inorganic boron compounds. Apart from studying the chemistry of the metal borates and other inorganic compounds, work is being done on their applications in corrosion inhibition, ceramics, fire retardants, glass and other fields, to make better use of the boron compounds already available.

Another section is concerned with the organic chemistry of boron and with certain closely related aspects of the modern boron chemistry that has recently aroused so much interest. Already the company is marketing such compounds as methyl metaborate (for extinguishing metal fires) and tri-n-butyl (for isolating alcohols from essential oils). This research section is aiming at the production of other boron compounds, particularly materials with high temperature resistance and exceptional chemical stability.

A third section is primarily concerned with reactions carried out at high temperatures. The preparation and properties of, for instance, elemental boron are being studied from a fundamental point of view; the company is already marketing both amorphous and crystalline boron. Metallic borides also feature in this section's programme, and these have created considerable interest for high-temperature uses, such as in rocket motors, and in zinc smelting. Boron tribromide is already being manufactured and research into this and other boron halides is continuing. Many of these compounds are themselves well-known but the field is a wide one in which much remains to be discovered.

Apart from these pure research sections, there is a technical service section to study the immediate problems of specific customers and the technical and development departments.

The laboratories are housed in a group of one-storey buildings surrounded by lawns. The inorganic research and technical service work is carried out in the largest of the laboratories, in the main block. The main block also houses the canteen, the library and the administrative offices. The other laboratories, which have only recently been equipped, are in a second block. Near them are workshops for the laboratory engineer and the glassblower who make special equipment as required.

Left—The inorganic chemistry laboratory at the new research centre, at Chessington, of Borax Consolidated Ltd.

Below—Exterior view of the main block.

Glister on the Orb is Gold

U.S. earth satellite has a plated finish

TO facilitate optical tracking and to provide protection from the elements in outer-space, the soon-to-be-launched earth satellite has been plated with a bright gold finish made by the Sel-Rex Corporation, of Nutley, New Jersey, U.S.A. The gold plating was also used to plate most internal parts and housings for instruments as a shield against corrosion and friction-heat.

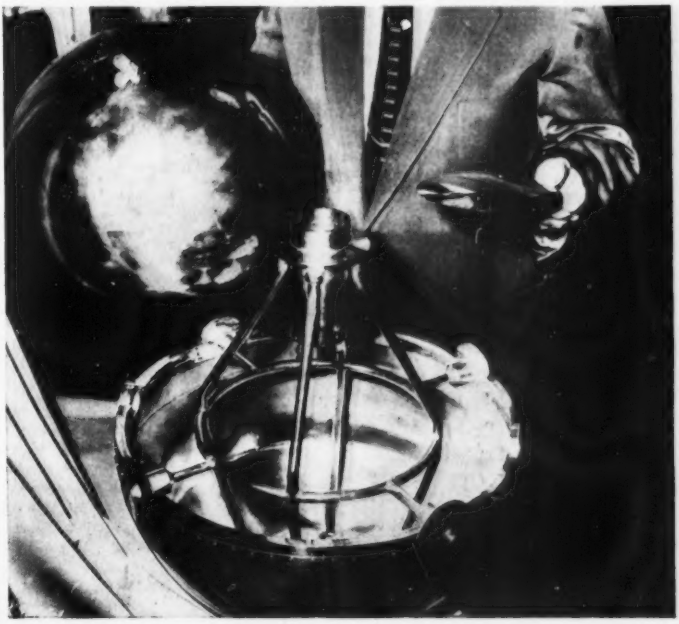
The launching is to take place some time during the current international geophysical year, and latest reports indicate that tests on the three-stage rocket that will catapult the sphere into space are almost complete. With the successful launching of the Russian earth satellite, and the impatient tone of the prestige-conscious U.S. Senate, scientists are trying to speed plans to get the 20-in. sphere into orbit.

Designated Project Vanguard, a joint Army, Navy and Air Force undertaking managed by the U.S. Chief of Naval Research, the crux of the entire programme is the collection of scientific data once the satellite is successfully orbiting the earth. In order properly to evaluate and compute data transmitted from the satellite, it must be tracked optically and by radio during its entire journey through space.

The tremendous stresses and strains and torturous atmospheric conditions to which the satellite will be subjected has called for some very special metallurgical properties in the materials of construction.

A thousand pounds of propellant are required for every pound of satellite and because it is the lightest of structural metals, in addition to having other unique physical characteristics, magnesium was selected as the basic material of construction. Brooks & Perkins, one of U.S.A.'s leading independent producers and fabricators of magnesium was awarded the contract to build the satellite's shell. Researchers had already decided on gold for the satellite's outer skin. This provides among other things, the maximum reflectivity so that " tracks " will be left in space for earth data-receiving stations to follow.

Before the gold plating specifications of the satellite were fixed, extensive experimental work was conducted by the Naval Research Laboratory to test adhesion and other characteristics of gold plating on magnesium. Many standard and proprietary gold plating formulations were tested before Self-Rex Bright Gold was specified. It is reported that, in the final analysis, this electroplating formulation was selected because its deposits retain all the desirable metallurgical properties of 24K gold in addition to being twice as hard, more dense and reflective.



Many internal parts and instrument housings were also gold plated.

P.V.C. COATED SHEET

NEWS of the commercial availability of a new type of coated sheet under the trade name " Stelvetite " has been released by John Summers and Sons Ltd., who have developed the product in co-operation with B.X. Plastics, Ltd.

It is a cold-reduced strip-mill product with a specially formulated Velbex P.V.C. coating. The P.V.C. is 0.014 in. thick and can be supplied in almost any colour. It is resistant to acids, alkalis, greases, detergents, and has excellent abrasion resistance. Its electrical properties are good and one important feature is that it is warm to the touch compared with uncoated steel.

There is little doubt that the potential industrial applications for this material are very wide, particularly as it can be bent, formed and deep drawn without damage to the coating.

EPOXY ADHESIVES

THE makers, Furane Plastics Inc., 4516 Brazil Street, Los Angeles 39, California, U.S.A., claim that the application of colourful vinyl films and sheets to other materials of construction has been made simpler by Epocast 126, a new solventless vinyl adhesive. Specifically developed for use with vinyl compounds, Epocast 126 provides a means of applying vinyl sheets to steel, aluminium, masonite, wood and other surfaces.

Solvents have been used in the past, though their effect upon vinyl sheets has sometimes caused wrinkling and loss of strength. With this adhesive the makers claim that it is now possible to bond rigid as well as most semi-rigid sheets to many materials. Epoxy adhesives have remarkable adhesion to many materials although they require a special formulation to achieve a bond to vinyl.

The bonding material will be useful to make automotive and aircraft interiors faced with decorative vinyls, the chemical installations of vinyl sheets and fabricated structures.

FOIL PACKS AT THE DAIRY SHOW

NEW trends and techniques in the use of aluminium foil for packing dairy products will be demonstrated by Venesta Ltd., the aluminium foil rollers, on their stand at this year's Dairy Show to be held at Olympia from October 22.

The stand itself will be a replica of a Queen Anne period dwelling-house, and will have two windows carrying displays of foils. A small lawn in the forecourt of the house will have as a centrepiece a revolving display of dairy products packed in Venesta foil.

Coinciding with the Dairy Show, the firm has organized its direct road delivery service to cover 20 counties in the U.K.

SYNTHETIC COATING GIVES ACID VAT LONG LIFE

" Caution — Acid " says the tag on this storage vat containing a liquor for pickling stainless-steel equipment used in the chemical industry.

The vat is seven ft. high with a diameter of eight ft. and is constructed of wooden staves. It has already given eighteen months continuous service without maintenance, and there is still no sign of deterioration. The secret? An internal lining of neoprene covered with " Hypalon," a synthetic elastomer recently introduced by Dupont of the U.S.A. — total thickness, about 6 mils.

The coating can be applied either as a paint or as a sheet lining. Distribution in the U.K. of both neoprene and Hypalon is by Durham Raw Materials Ltd., 1-4 Great Tower Street, London.

PAINT TECHNOLOGY

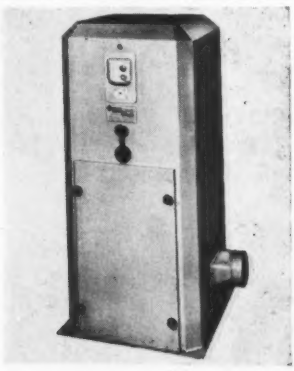
A COURSE of five lectures on " Microbiology in Relation to Paint Technology " is being given at the Borough Polytechnic, Borough Road, London, S.E.1. The course started on September 27. The lecturers are Messrs L. D. Galloway, V. E. MacKenzie and G. Lester.

EXTRACTORS FOR DUST COLLECTION

TREMENDOUS strides have been made in recent years to wards solving the problems of air pollution, dust collection and the salvaging of valuable materials in air-borne debris.

Often, a multi-point installation is unavoidable, but in many industries unit-type collectors can be installed to advantage.

A Birmingham firm, A. E. Griffiths (Smethwick) Ltd., Booth Street, Handsworth, has recently announced details of two units that were originally designed to provide efficient dust extraction at its source with a high degree of separation and collection of the by-products.



The models have a compact form.

The units are similar in design and construction, varying only in size and capacity. The smaller of the two, the " Micronette " was designed and produced first for singlewheel grinders and other small machines, but later it was decided to make another larger unit — the " Micro-master."

Unit-type collectors offer many advantages. For example, very little floor space is occupied and the cost of installation is minimized ; greater flexibility of plant layout becomes possible and large-diameter ducting can be avoided. But, to operators, the greatest asset where a batch installation is used instead of a single large plant, is the unit's ability to operate singly, which can often greatly reduce the cost of a production stoppage.

The collectors can be applied to most cutting or abrasive operations on many different materials, and where a potential danger source exists, such as the fire and explosion risks inherent in the fabrication of magnesium or titanium, safety controls are available to keep the risk to a minimum.

Operation

When a mixture of air and dust particles is drawn into the collector, the dust is first separated by filtration and is collected into a removable tray while the air is discharged to atmosphere. The filtration is in two stages, the first caused by a sudden drop in velocity when the intake mixture reaches the base of the unit, and a secondary separation when the released air passes through textile filtering sleeves.

The filtered air, after being used in the cooling system for the unit's electric motor, is discharged vertically to reduce the effects of draught. Ducting can be attached to this air outlet if necessary to carry noxious fumes to outside atmosphere.

Undoubtedly, dust and dirt are responsible for a lot of the labour and maintenance cost caused by abnormal machine wear, and for unhealthy working conditions which can lead to dissatisfied employees. Any system such as this quickly repays its original capital cost.

TECHNICAL *and* INDUSTRIAL APPOINTMENTS

Mr. E. S. Hiscocks, M.Sc., F.R.I.C., has been appointed director of the U.K. scientific mission in the **British Commonwealth Scientific Office** in Washington. He will also be attaché for scientific questions to the British embassy there. Mr. Hiscocks, who has been secretary of the National Physical Laboratory for the past 12 years, is expected to take up his appointment later in the year. He will succeed Mr. H. J. Hadow, B.A., B.Sc., who, on completion of his term of office in Washington, will return to duty with the **Department of Scientific and Industrial Research** in England.

* * *

The National Union of Manufacturers, 6, Holborn Viaduct, London, E.C.1., announces the appointment of Mr. Victor Berry as secretary of their South Wales branch.

Mr. Berry, at one time engaged on production with Armstrong Siddeley Motors and Armstrong Whitworth Aircraft, will be remembered by many for his work with the Institution of Automobile Engineers prior to its merger with the Institution of Mechanical Engineers.

The address of the South Wales branch of the N.U.M. is 53,Cathedral Road, Cardiff (Tel. 33806).

* * *

Mr. G. D. Denyer, B.Sc., has joined the staff of **Aluminium Laboratories Ltd.,** Banbury, Oxon., as head of the casting section of the metallurgy division.

After graduating from the University College of South Wales, Cardiff, Mr. Denyer spent two years with the B.N.F.M.R.A. as a research bursar, working on the electroplating of aluminium. He then took a post with the Glacier Metal Co., Wembley, where he carried out research and development work on aluminium-tin bearings for motor cars, subsequently being appointed manager of the pilot production plant.

Mr. L. Roullier, A.M.I.E.E., M.E.I.C., A.A.I.E.E., has been appointed head of the recently formed electrical division of **Aluminium Laboratories Ltd.** For this appointment Mr. Roullier was transferred from Aluminium Union Ltd., London, where he was engaged on development engineering associated with the use of aluminium in electrical apparatus. Prior to joining the Aluminium Limited Group of Companies in 1954 he held an appointment with Johnson and Phillips Ltd. for six years, with whom he served a post-graduate apprenticeship course, and was afterwards engaged on development and contracts work in the U.K. and Pakistan.

* * *

Mr. George E. Drake has been appointed vice-president in charge of sales of **Electro Metallurgical Company,** Division of Union Carbide Corporation. Formerly he was assistant general manager of the Corporation's silicone division.

* * *

After serving a two year tour of duty with the United States Army, Mr. James R. Schaffner has been participating in an intensive research programme for the **Schaffner Manufacturing Co. Inc.,** Pittsburgh 2, Pa., U.S.A.

On completion of this programme, Mr. Schaffner will be working in sales, under the direction of Mr. Paul E. Schaffner. The firm manufactures the metal-centre aircooled (bias type) buffs and buffing composition lines.

* * *

Mr. Edwin King has been appointed assistant company secretary of **Black and Decker Ltd.,** Harmondsworth, Middlesex.

Mr. King returned last month from Australia, where for six months he had been financial adviser during the setting up of Black & Decker (Australasia) Pty. Ltd., the company's new plant at North Croydon, near Melbourne, Victoria.

Mr. King joined Black & Decker in 1954 as accountant, and in January 1956 was appointed budget controller. He qualified as a chartered accountant while employed by Rowley Pemberton & Co., London, and later was for three years the managing clerk of Allan Charlesworth & Co., a London firm of chartered accountants.

* * *

A number of new appointments are announced by **Sparklets Ltd.,** the Tottenham engineering firm, and among these, Mr. J. H. Cope has been appointed superintendent of the product finishing section, and Mr. J. H. Briston has been appointed as chemist.

* * *

Aluminium Union Limited, The Adelphi, John Adam Street, London, W.C.2, announce that Mr. George T. Field, formerly of the Board of Trade, has been appointed to an executive position at their London Office.

OLD WINE IN NEW BARRELS

IN past years exports of wine from Hungary have been held up for lack of wooden barrels, so at the request of Monimpex, Hungary's wine export organization, the Metal Research Institute in that country has produced the prototype of a 110-gallon wine barrel made of aluminium.

The aluminium barrel has the advantage of being only a fifth of the weight of wood and less liable to damage.

A wine-resistant coating on the inside of the barrel preserves the taste, colour and bouquet of the wine. Aluminium beer barrels were introduced last year.

PLASTICS SHOW WIDENS SCOPE

THE next plastics exhibition and convention, to be held at Olympia, London, June 17-27, 1959, will change its title from " British " to " International ".

The fifth event of its kind, and the second to show international exhibits, it will again be organised by the journal *British Plastics* with full support of the British Plastics Federation.

It will be a focal point and international forum for views and ideas on plastics technology, and a market place for the sale of plastics materials, machinery and finished products, on a world-wide scale.

Of the 90,000 people who attended the 1957 Exhibition, 6,000 were from overseas, representing 84 different countries.

Full details may be obtained from the organizers, *British Plastics*, Dorset House, Stamford Street, London, S.E.1.

Concentration

THE plating chemical section of W. Canning and Co. Ltd., electroplating engineers and chemists, Birmingham, have been concentrated in larger accommodation at the company's Albion works, where modernized equipment will take over the production of plating salts and chemicals formerly carried on at the Snow Hill and Bagot Street factories.

NEW COMPANIES

" Ltd " is understood, also " Private Co." Figures = Capital, Names = Directors, all unless otherwise indicated.

Enamelling (Denton), 96, Town Lane, Denton, Manchester. August 13. £1,000. J. Allen, F. W. Edgley, A. Fosner.

Parsecs, Haymarket Court, 31/2, Haymarket, S.W.1. August 23. £100. To carry on bus. of manufacturers of and dealers in industrial and domestic, electronic, optical and electrochemical components, etc. Mrs. K. F. Knott, D. T. Wilkerson.

Clairmonte Bros. Enamelling, Imperial Works, Shankling Road, N.8. August 30. £100. E. H. Clairmonte, C. M. Clairmonte, Lynette Clairmonte.

Ludlow Brothers, Pedmore Road, Lye, Stourbridge. August 30. £75,000. To take over the bus. of holloware manufacturers carried on at Lye by Ludlow (Holdings) Ltd., etc. J. Bayliss, W. C. Sproson, J.D. Keast and W. S. Grainger.

Harry Luckman Design and Research, 9, Queens Road, Coventry. September 2. £2,000. To carry on bus. of designers and research workers to the engineering industry, etc. H. Luckman.

A. and F. Parkes and Co. (London), 96/98, Leadenhall Street, London, E.C.3. September 6. £100. To acquire the branch of the bus. of A. and F. Parkes and Co. Ltd. known as the " London Business " being galvanizers and merchants and carried on by that company at Leadenhall Street, E.C.3., etc. E. G. Parkes, S. R. Parkes.

Extrusion (Holdings), 10, New Court, Lincolns Inn, W.C.2. September 6. £50,000. To carry on bus. of iron and steel stockholders, metal and alloy makers, refiners, etc. J. H. Fischel.

Marine Anti-Corrosion Services. September 5. £2,000.

Precious Metal Depositors. September 5. £5,000. R. F. Naylor, E. F. Marlow.

From the Register compiled by Jordan & Sons Ltd., 16, Chancery Lane, London, W.C.2.

TRADE and TECHNICAL PUBLICATIONS

" The Bonderizer ": The August - September issue of this journal published by the Pyrene Co. Ltd., Metal Finishing Division, Great West Road, Brentford, Mddx., is devoted to the S.B.A.C. Farnborough Display, and to the users of the firm's range of metal finishing processes in the aircraft industry.

Space limitations have prevented an exhaustive survey of the industry but within its covers a remarkably wide field is covered including the uses of Parkerizing and Bonderizing in various aircraft engines and components.

Also included is an extract from a paper by P. G. Patten, A.I.M., Chief Metallurgist and Laboratory Superintendent of Briggs Motor Bodies Ltd., Swaythling, Southampton, on the cold forming of titanium*, in which a new Bonderizing process is employed.

* Full details of the methods used appeared in the October issue of our sister-journal " *Sheet Metal Industries.*"

" Radyne Review ": The first number of this review published by Radio Heaters Ltd., Wokingham, Berks., describes some methods of induction heating used in the motor industry.

High frequency heating plays an important role in the present trend towards automation in the motor car industry. Induction heating equipments are specifically designed for hardening, annealing, stress-relieving and other heat-treatment processes involved in the manufacture of many car components. The equipments are ideally suited to process control and many installations incorporate completely automatic feeding mechanisms.

The review describes and illustrates the hardening of valve stems and starter flywheel-ring gears, the softening of splines of hypoid-pinion gears, the stress relieving of differential gear-box castings, and the upsetting of stabilizer bars.

The equipments illustrated are typical of many where the induction heating equipment is an integral part of a special purpose machine. In this way, the heat treatment is incorporated in the actual manufacturing process, so that a " flow line " production is achieved.

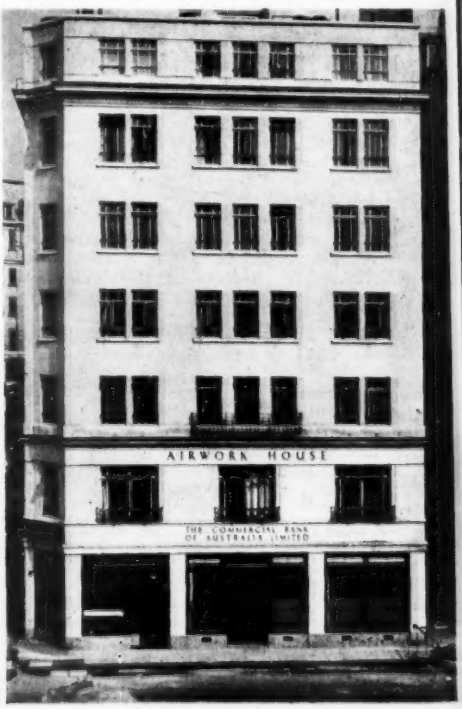
(*News continued in page* 436)

NEW LONDON LANDMARK IS H.Q. FOR BORAX COMPANY

During last month, Borax and Chemicals Ltd., formerly at Kings Bourne House, 229 High Holborn, London, W.C.1., moved their headquarters office to 35 Piccadilly, London, W.1. Telephone: Regent 2751.

The new address is a recent addition to the London landscape and offers only its flank to Piccadilly. Its facade fronts Swallow Street, a crosspiece to the letter A formed by Regent Street and Piccadilly, and at its back is the Piccadilly Hotel.

A view of the building's imposing flank as seen from Piccadilly is shown on the right.



Latest Developments in PLANT, PROCESSES AND EQUIPMENT

METALLISING SPRAY GUN

WHAT is claimed to be an entirely new pistol for metal spraying equipment has been announced by Metallisation Ltd., Barclays Bank Chambers, Dudley, Worcs. (Fig. 1).

Known as the Mark 33, the pistol is the successor to the Mark 16 and has a wide range of speeds made possible by a unique magnetic control. Frictionless, this control gives infinite variation without loss of power coupled with the minimum of wear.

To change from one size of wire diameter to another is effected simply by changing the wire nozzle. The pistol is well-balanced, and the makers claim that it is a considerable advance on anything yet produced.

ULTRASONIC CLEANING BATH

THE L.276, a new type of ultrasonic cleaning bath for small components and precision piece parts, is announced by Mullard Ltd., Torrington Place, London, W.C.1., as being in full production (Fig. 2).

The company's considerable experience in the development and application of ultrasonic techniques shows a specific need for a compact, hand-fed cleaning bath to supplement conveyorized equipment for the rapid and effective cleaning of small articles.

Although their history is relatively short, ultrasonic cleaning techniques have proved highly successful in all those industries where they have been adopted. In many cases, almost spectacular improvements in cleaning standards, with material reduction in processing times, have been achieved over conventional methods.

The outstanding performance of the L.276 is attributable largely to a new design of low-frequency radial transducer, developed specifically for the equipment. This transducer has two important advantages, both of which result in improved cleaning efficiency and shorter processing times. First, it effectively focusses the cavitation intensity in the centre of the cleaning fluid container, where the component would be situated. Second, the cavitation effect is directed equally to all sides of the component simultaneously: therefore, unless exceptional requirements call for multi-stage processing, the entire surface area of the article can be cleaned with one dip.

Yet another advantage of the equipment is that, due to its special construction, hot solvents may be used direct. The fluid container (a standard Pyrex glass beaker) and the transducer are contained in a water jacket. The water serves not only to cool the transducer, but also to couple the ultrasonic energy to the cleaning fluid.

The beaker is easily removable — it simply stands in position in the centre of the transducer annulus; multi-stage processing with a variety of cleaning agents when exceptionally high cleanliness is required can therefore be carried out by simple substitution of beakers. Furthermore, since only the beaker is in direct contact with the fluid, no problems arise with the cleaning of the equipment.

Capacity of the beaker is 250 ml, and its dimensions are approximately 28 in. diameter by 4½ in. deep.

CHEMICAL POLISHING SOLUTIONS FOR COPPER ALLOYS

ALBRIGHT & Wilson (Mfg.) Ltd., 1, Knightsbridge Green, London, S.W.1., have completed development of two additions to their range of "Phosbrite" chemical polishing solutions. These solutions, available initially on an experimental basis, are Phosbrite 183, for treating basis and cartridge brass, and Phosbrite 184, for gilding metals.

The solutions produce bright, highly reflective surfaces on the metalwork in 1 to 3 minutes. The firm claims that their development represents an important advance in quality of finish, ease and accuracy of control and economy in this type of process. No desmudging is required, the polished metal being rinsed in cold water and then dried. Surfaces may subsequently be nickel-chromium plated or lacquered, or left in their chemically polished state.

The polishing tanks can be made of stainless steel, P.V.C.-lined mild steel, chemical stoneware or glass, and solutions are operated at optimum temperatures of 65 C. and 60°C. respectively. Fume extraction equipment is essential and may be made of P.V.C.

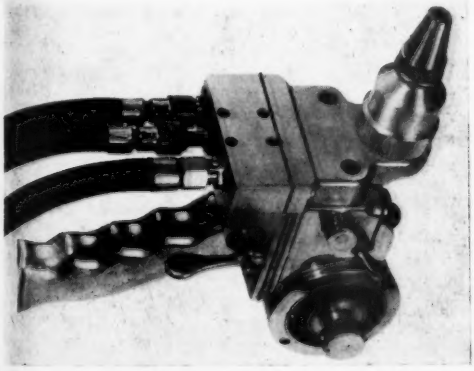
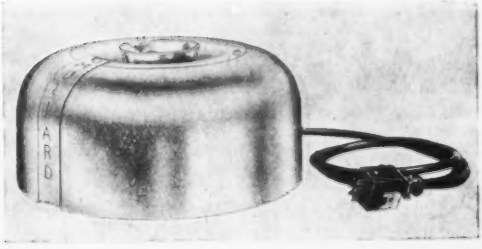


Fig. 1 (left)—Metallising spray gun

Fig. 2 (below)—Ultrasonic cleaning bath



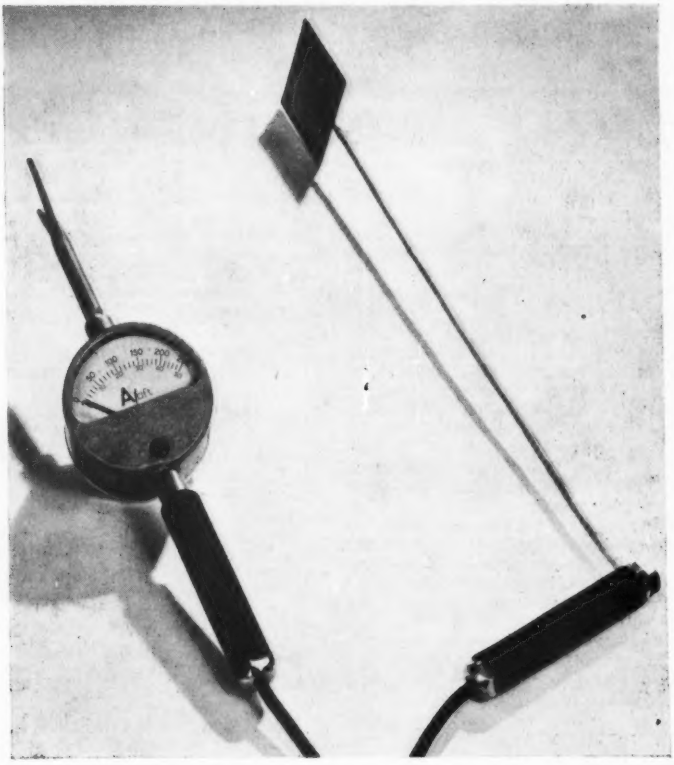


Fig. 3.—Current-density indicator.

PORTABLE CURRENT-DENSITY INDICATOR

THE latesta ddition to the range of 'English Electric' instruments is a portable current-density indicator, which is an invaluable aid to production in the electro-plating industry. By giving a direct reading in amperes per square foot, this indicator enables the current density in the electrolyte at any point of any number of loaded electro-plated vats to be checked rapidly, and their operating currents adjusted for maximum plating efficiency and consistency of quality. (Fig. 3).

The apparatus, marketed by the English Electric Co. Ltd.,Instruments Sales & Contracts Dept., Stafford, consists of a robust moving-coil ammeter connected in series with a plate electrode of known surface area. The electrode is immersed in the electrolyte between the component to be plated and the anode. When contact is made to the work bar through the forked spike on the ammeter case, a direct indication of current density in the vat at that point is given on the ammeter dial.

Two electrodes are supplied, one of stainless steel for use in stannate tin, zinc and cadmium vats where current density does not exceed 50 amperes per square foot, and a second patented glass-backed electrode for use in chromium and bright-nickel vats where current density is up to 250 amperes per square foot. Selection of the correct electrode enables readings with an accuracy of ±5 per cent to be readily obtained.

ELECTRICALLY DRIVEN COMPRESSORS

REDUCTION of compressor noise coupled with a reduction in wear, is an object being sought by most leading compressor manufacturers. For many applications, the installation of diesel units leads to a measure of objection due to the noise level created, this being particularly applicable to work in built-up areas and on sites where noise constitutes a source of irritation to those engaged in other occupations.

A substantial reduction of noise level has already been achieved by the Consolidated Pneumatic Tool Co., Ltd., 232, Dawes Road, London, S.W.6., in their oil flooded "Power Vane" rotary compressors and this has been followed by the introduction of electric motors for the complete range. Further advantages accruing from this type of compressor lie in the great economy of operation, the maintenance costs of electric motors being negligible when compared with those of diesels.

The Consolidated Pneumatic electrically operated "Power Vane" rotary compressor consists basically of two circular shaped chambers mounted in line with an electric motor. Two rotors, mounted on a common shaft, are positioned eccentrically to the casing of the chambers and carry a number of sliding vanes, inserted radially in longitudinal slots in the rotor. Thus as the shaft rotates, the vanes form a number of sectors of increasing and then diminishing size as they follow the changing contour of the chamber.

Air is admitted through an inlet port when the vanes are approaching maximum extension. As soon as the vanes pass the inlet port, they begin to retract back into the slots in the rotor and the sector decreases, compressing the air until the discharge port is reached, when the compressed air is released to the inlet port of the second compression chamber and the cycle is repeated.

Oil flooding of the compressor achieves thorough lubrication, cooling and sealing of clearances. As cooling takes place at the moment when air temperatures would otherwise start to rise due to compression, the compression chambers and rotor are themselves kept cool and air is delivered at least 100°F. cooler than would be the case with a two stage piston type portable compressor of the same capacity.

The absence of pistons, crankshaft, valves and clutch, coupled with oil flooding results in the minimum of wear, and the performance data of the diesel powered units shew many thousands of operating hours without any time lost through breakdowns.

The new electrically operated units, for surface use are powered by Brush and English Electric direct coupled, high torque, squirrel-cage motors fitted with Star Delta starters. Where flameproof operation is required, the units may be supplied with Brush, English Electric, Metropolitan Vickers and Morley flameproof motors.

The units are run at lower rpm than when diesel powered. Thus the models 120RE, 175RE and 210RE are designed for service at 1450 rpm and deliver 100, 135 and 160 cfm FAD respectively while the 365RE operates at 1460 rpm and delivers 300 cfm FAD, pressures in each case being 100 psi. The largest unit in the range, the 600RE delivers 510 cfm FAD at 1480 rpm.

(*Continued in page* 436)

The more intricate the design the greater the saving

Aluminium articles of intricate design can be polished easily and cheaply in Albright & Wilson's 'PHOSBRITE' solutions.

As a complete finish or, alternatively, before plating or anodizing, chemical polishing with 'PHOSBRITE' solutions saves time and money over mechanical methods.

CHEMICAL POLISHING WITH

PHOSBRITE (R)

saves time & money

For full information write to
ALBRIGHT & WILSON (Mfg.) LTD.
METAL FINISHING DEPARTMENT
1 KNIGHTSBRIDGE GREEN
LONDON : SW1

TBW/419

Plant, Processes, etc.

(*Continued from page* 434)

New Fuel Improver for Oil Fired Furnaces using Residual Fuel Oils

A FUEL improver for residual fuel oils which has been developed and proved in France over a number of years is now available in Britain and the Commonwealth. It is being manufactured by the Amber Chemical Co. Ltd., 11a, Albemarle Street, London, W.I., and marketed under the name "Amber Desulfurol (SSR. 509)."

It is claimed that the addition of this product to residual fuel oils will reduce the formation of sulphur trioxide by 50 per cent to 75 per cent., increase average CO_2 readings by 3 per cent. to 4 per cent. and will bring about an appreciable reduction in fuel consumption. These claims are based on experience in almost every industry over several years in France and during trials recently carried out in England, reports of which are available from the manufacturers.

In addition to the financial economies indicated by the test results, an important practical effect of the use of Amber Desulfurol (SSR. 509) is the reduction not only of sulphur trioxide, but also of soot and smoke. This is of particular value to industries where atmospheric pollution can seriously hamper quality of production.

Metal Finishing News. (*Continued from page* 432)

MEETINGS OF THE MONTH

October 21

Institute of Metal Finishing (London Branch). Joint meeting with the Society of Chemical Industry. "Accelerated Corrosion Testing of Chromium-Plated Articles —Sulphur Dioxide Test," by J. Edwards, and "The Acetic-Acid Salt Spray Test," by J. H. Hooper, at 14 Belgrave Square, S.W.1, at 6.30 p.m.

October 25

Institute of Metal Finishing (Sheffield and N.E. Branch). "Brains Trust on Silver," at the Grand Hotel, Sheffield, at 7.00 p.m.

November 5

Institute of Metal Finishing (Midland Branch). "Acceptance Tests," by I. Walker, at James Watt Memorial Institute, Great Charles Street, Birmingham, at 6.30 p.m.

November 6

Institute of Metal Finishing (Scottish Branch). "Metal Finishing by Vacuum Coatings," by F. C. Weill, at the Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow, at 7.30 p.m.

November 7

Institute of Metal Finishing (North West Branch) Joint meeting with Organic Finishing Group. "Recent Developments in Electrostatic Spraying," by R. Tilney, film and lecture, at Engineers' Club, Albert Square, Manchester, at 7.30 p.m.

November 12

Metal Finishing Association. "Some Aspects on Advertising," by a representative from Midland I.T.V. Luncheon meeting at the Farcroft Hotel, Rookery Road, Handsworth, Birmingham 21.

November 15

Oil and Colour Chemists' Association (Midlands Section). "Vinyl Polymers in Solution — their use and future", by D. J. Cowley, B.Sc. 6.30 p.m. Regent House, St. Philip's Place, Birmingham.

November 18

Institute of Metal Finishing (London Branch). "Production of Multi-Colour Designs of Anodised Aluminium," by V. F. Henley, at the Northampton College, St. John Street, E.C.1.

November 26

Metal Finishing Association. Dinner Dance at the Pavilion Suite, Warwickshire County Cricket Ground. 7 p.m. onwards.

Classified Advertisements

Prepaid rates: FIFTEEN WORDS for 7s. 6d. (minimum charge) and 4d. per word thereafter, or 24s. per inch. Box number 2s. 6d., including postage of replies.

SITUATIONS VACANT

METAL FINISHING CHEMIST

required by the Central Research Unit of S. Smith & Sons (England) Ltd. for interesting development work. Metal finishing and engineering experience desirable but not essential.

Salary in accordance with age and experience.

Applications to Personnel Officer,
15, Carlisle Road,
London, N.W.9.

VAUXHALL MOTORS LTD., LUTON, Beds., require a **PLATING CHEMIST** to exercise technical control over a high production plating shop consisting of a number of large automatics for copper and bright nickel-chromium plating as well as smaller automatic units for other metals. The applicant should be capable of carrying out plating solution analyses and be familiar with modern plating solutions and techniques.

Applications should be submitted in writing to the Staff Employment Manager, giving full details of education, experience and salary required.

Situations Vacant (*contd.*)

ESTIMATOR
(ENGINEERING)
with knowledge of
ELECTROPLATING TRADE

required with a view to taking over senior position with leading Electroplating Supply House in Home Counties area.

Excellent opportunity for hard-working ambitious man seeking advancement.

Pension and Life Assurance Scheme available.

Existing Staff advised.

Write stating age, experience and initial salary required to Staff Manager, Box No. 528, METAL FINISHING JOURNAL.

Applications will be treated in strictest confidence.

FRIT—FORMULATION CHEMIST to undertake development research on vitreous enamels at a modern frit factory at Warrington. Applications stating age and experience in ceramics are invited from graduates and other qualified persons addressed to Radiation Frit Factory, Grappenhall Works, Warrington, Lancs.